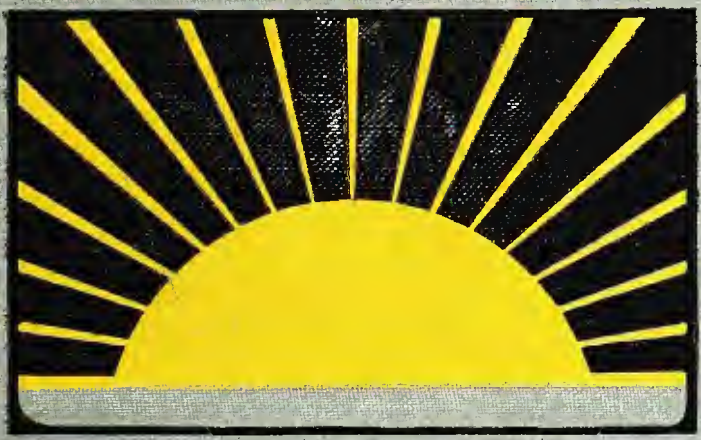
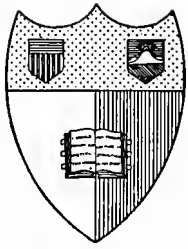
PIONEERS OF PROGRESS



MEN OF SCIENCE

HERSCHEL

HECTOR MACPHERSON



L. F. Abbott, pinxit — Emery Walker, photographer

SIR WILLIAM HERSCHEL, K.H., F.R.S.
From the picture in the National Portrait Gallery

PIONEERS OF PROGRESS

MEN OF SCIENCE

EDITED BY S. CHAPMAN, M.A., D.Sc., F.R.S.

HERSCHEL

BY THE REV.

HECTOR MACPHERSON

M.A., F.R.A.S., F.R.S.E.

AUTHOR OF

"ASTRONOMERS OF TO-DAY," "A CENTURY'S PROGRESS IN ASTRONOMY"

"THE ROMANCE OF MODERN ASTRONOMY," ETC. ETC.

LONDON:

SOCIETY FOR PROMOTING

CHRISTIAN KNOWLEDGE

NEW YORK: THE MACMILLAN COMPANY

1919

CONTENTS.

CHAPTER I.

EARLY YEARS.

"UNIVERSAL history—the history of what man has accomplished in this world," says Carlyle, "is at bottom the history of the great men who have worked here." It must be admitted that Carlyle under-estimated the labours of the innumerable lesser workers in all departments of human activity, that he overlooked the part played by mighty world-movements in the realm both of thought and of action and the influence, even on great men, of what has been called the "time-spirit". Still, Carlyle's dictum — slightly qualified — is fundamentally true. A great personality is a creative force; he gives more to his age and to posterity than he receives from his age or the ages before him.

The history of astronomical science has been dominated in a remarkable degree by great creative personalities—pioneers of astronomical discovery. In the front rank of these distinguished men, posterity has placed the name of William Herschel.

The illustrious astronomer came of an old German family, and was descended from one of three brothers, who, on account of steadfast devotion to the principles of Protestantism, were driven out of Moravia in the early part of the seventeenth century and compelled to seek refuge in Saxony. Hans Herschel, one of these brothers, settled at Pirna in Saxony. His second son, Abraham, born in 1651, acquired some distinction as a landscape-gardener. He learned gardening in the

Elector's gardens at Dresden, and was afterwards employed, until his death in 1718, at the country-seat of Hohentziatz, in the principality of Anhalt-Zerbst, near Magdeburg. According to the short account of the family given by his illustrious grandson, "he had also a good knowledge of arithmetic, writing, drawing, and music". The last-named talent he bequeathed to his youngest son, Isaac, born at Hohentziatz on 14th January, 1707. In a brief review of his life which he left behind him, Isaac explains that it was the desire of his parents that he should follow in his father's line of life. After the death of his father, his elder brother Eusebius procured for him a situation in the gardens at Zerbst. But he had, in his own words, "lost all interest in gardening". "As I had already at Hohentziatz procured a violin and learned to play it by ear, I took proper lessons at Zerbst from an hautboy-player in the court-band. I also bought an hautboy, and was never so happy as when I could occupy myself with music." At the age of twenty-one, having decided to follow out music as his life-work, he went to Berlin to study. Finding "the Prussian service as a bandsman very bad and slavish," he went to Potsdam and took lessons for a year. From Potsdam he made his way to Brunswick, and thence to Hanover, where in August, 1731, he was engaged as hautboy-player in the Foot-guards. Hanover was destined to be his home, and in 1732 he married Anna Ilse Moritzen, the daughter of a citizen of the neighbouring town of Wenstadt. They had a family of ten, of whom six—four sons and two daughters—reached maturity. Of these, the third, Friedrich Wilhelm, born at Hanover on 15th November, 1738, became one of the greatest astronomers—indeed, one of the greatest men of science—of all time.

Isaac Herschel seems to have been not only a man of high musical talent, but also of wide general culture. And despite the mother's dislike to learning and her

lack of interest in intellectual things, all the members of the family—with the exception of the elder daughter, Sophia—inherited something of their father's ability. All four sons—Jacob, William, Alexander, and Dieterich—were eminent musicians; and the younger daughter, Caroline Lucretia, born 16th March, 1750, also accomplished in music, has earned a distinction only second to that of her distinguished brother, whose life-work she shared.

In her memoirs, written in old age, Caroline Herschel has given some interesting reminiscences of her father. "My father," she says, "was a great admirer of astronomy and had some knowledge of that science: for I remember his taking me on a clear frosty night into the street to make me acquainted with several of the most beautiful constellations, after we had been gazing at a comet which was then visible. And I well remember with what delight he used to assist my brother William in his various contrivances in the pursuit of his philosophical studies, among which was a neatly turned 4-inch globe, upon which the equator and ecliptic were engraved by my brother."

Despite his remarkable abilities, Isaac Herschel's whole life was spent in straitened circumstances: the post of bandsman in the Hanoverian Guards was not a lucrative one, and he was forced to augment his income by private tuition. In addition, his poverty was aggravated by chronic ill-health. After the battle of Dettingen in 1743, the Guards remained all night in the field. Isaac Herschel lay in a wet furrow, and as a result of that night's exposure, he contracted an asthmatical affection which impaired his health permanently and ultimately caused his premature death on 22nd March, 1767. Having no wordly goods to bequeath to his children, he sought to educate them as completely as his limited means would allow. From their earliest days, their father instructed them in music. William Herschel, in the short account

of his life already referred to, tells us that his father "taught me to play on the violin as soon as I was able to hold a small one made on purpose for me. . . . Being also desirous of giving all his children as good an education as his very limited circumstances would allow, I was at a proper time sent to a school where, besides religious instructions, all the boys received lessons in reading, writing, and arithmetic; and as I very readily learned every task assigned me, I soon arrived at such a degree of perfection, especially in arithmetic, that the master of the school made use of me to hear younger boys say their lessons and to examine their arithmetical calculations."

At the age of fourteen and a half, young William Herschel entered the band of the Hanoverian Guards, on 1st May, 1753. His school life was at an end, but his education was only beginning. For over two years he received private lessons from a teacher named Hofschläger, who afterwards filled an important post at Hamburg. These lessons included languages, logic, ethics, and metaphysics. In those early years Herschel's thirst for knowledge seems to have been insatiable. "Although," he wrote in after years, "I loved music to excess and made considerable progress in it, I yet determined with a sort of enthusiasm to devote every moment I could spare to the pursuit of knowledge, which I regarded as the sovereign good, and in which I resolved to place all my future views of happiness in life."

This intellectual keenness was undoubtedly stimulated by the home environment. The mother, it is true, was hostile to intellectual ambition; she was a typical German *Hausfrau*, with no sympathy for aspirations; but, as before mentioned, Isaac Herschel encouraged his sons to talk and think on scientific and philosophical subjects. Caroline Herschel, then a little girl about five years of age, has given a very interesting glimpse into this period.

"My brothers," she says, "were often introduced as solo performers and assistants in the orchestra of the court, and I remember that I was frequently prevented from going to sleep by the lively criticism on music on coming home from a concert, or conversations on philosophical subjects which lasted frequently till morning. . . . Generally their conversation would branch out on philosophical subjects, when my brother William and my father often argued with such warmth that my mother's interference became necessary when the names Leibnitz, Newton, and Euler sounded rather too loud for the repose of her little ones, who ought to be in school by seven in the morning."

The family circle was temporarily dispersed in the end of 1755. The times were stormy: the Seven Years' War was raging: a French invasion of England was expected, and the Hanoverian Guards were drafted across the North Sea. Accordingly, Isaac Herschel and his two sons left Hanover with the regiment. Embarking at Cuxhaven in the end of March 1756, they reached Chatham after a passage of sixteen days. The Guards were encamped successively at Maidstone, Coxheath, and Rochester. The Herschels' sojourn in England was by no means profitless. At Coxheath as well as at Maidstone, Herschel tells us, "my father, my eldest brother and myself made several valuable acquaintances with families that were fond of music, and which, on mine and my brother's return to England, proved of great service to us". At Maidstone, too, young William Herschel purchased a copy of Locke's "Essay on the Human Understanding". The perusal of this volume—the only thing he took with him from England—not only stimulated his interest in philosophy, but familiarised him with the English language.

In the end of 1756, the Guards were ordered back to Hanover, owing to the French threat to the country. Early in the following year, the regiment went into the

campaign which culminated in the disastrous battle of Hastenbeck, 26th July, 1757. During the campaign they were many times forced to encamp in the wet furrows of ploughed fields. At Hastenbeck, the band was almost within reach of gunshot. Accordingly, Isaac Herschel advised his son to consider his own safety. Young Herschel thereupon, in his own words, "left the engagement and took the road to Hanover, but when I arrived there, I found that having no passport I was in danger of being pressed for a soldier". At that time Herschel was not technically a soldier, but a member of the band. Accordingly, he returned to the regiment, only to find that "nobody had time to look after the musicians—they did not seem to be wanted". The forced marches in the hot weather told on the lad's health, and his father advised him to leave the service. "In September, my father's opinion was, that as on account of my youth I had not been sworn in when I was admitted to the Guards, I might leave the military service. Indeed, he had no doubt but that he could obtain my dismission, and this he after some time actually procured (in 1762) from General Spörcken, who succeeded General Sommerfeld."

The formal discharge paper is in existence and was printed for the first time in the "Collected Scientific Papers of Sir William Herschel," published in 1912. Dr. Dreyer, in his introductory sketch of Herschel's life, gives it as his opinion that "the existence of this formal discharge paper puts an end to the legend, too long and too readily believed, that he deserted from the army and that he received a formal pardon for this offence from George III on the occasion of his first audience in 1782". Whether Herschel was technically a deserter or not, it is very difficult to determine. In some notes furnished in later years to the editor of a Göttingen scientific periodical, Herschel said: "In my fifteenth year, I enlisted in military service, only remaining in the army, however,

until my nineteenth year, when I resigned and went over to England." On the other hand, as already noted, he gives it as his father's view that he was not really a soldier at all. The formal discharge paper is dated 29th March, 1762, so that if William Herschel was ever actually a unit of the army, the discharge paper merely registered an accomplished fact: he had been out of the army and out of the country for four and a half years. Whether or not he was *ipso facto* a soldier by virtue of his position in the band, there can be no doubt that his departure for England was actuated by the desire to avoid being recalled to the colours. The evidence of his sister Caroline, then a little girl of seven, is decisive on this point. "I can now comprehend," she says, "the reason why we little ones were continually sent out of the way, and why I had only by chance a passing glimpse of my brother as I was sitting at the entrance of a street door, when he glided like a shadow along, wrapped in a greatcoat, followed by my mother with a parcel containing his accoutrements. After he had suceeeded in passing unnoticed beyond the last sentinel at Herrenhausen, he changed his dress. . . . My brother's keeping himself so carefully from all notice was undoubtedly to avoid the danger of being pressed, as all unengaged young men were forced into the service. Even the clergy, unless they had livings, were not exempted."

At Hamburg, William Herschel was joined by his brother Jacob, and they embarked together for England. Arriving in London, they were greatly assisted by the friends whom they had made on the occasion of their previous visit. Nevertheless, they seem to have had a hard struggle. William Herschel had not half a guinea in his possession when he arrived in London. He went into a music shop and asked if he could be of any use in copying music. An opera was placed in his hands, and his promptitude in returning the copy so impressed the master of the shop that he kept him in his employment for a

considerable time. Jacob Herschel contrived to gain a livelihood by teaching music. At length, the brothers found that they could not make a living in London. Accordingly, Jacob decided to return to Hanover in the autumn of 1759 to compete for a place in the court orchestra, which he was successful in gaining. For a time, William was, in his own words, "involved in great difficulties". Fortunately, however, he succeeded in procuring an appointment in Yorkshire. The Earl of Darlington, Colonel of the Durham militia, was desirous of obtaining a good musician as leader of the band. Herschel's name was brought to his notice, and he received the offer of the post, which he accepted and held for two years. These two years appear to have been very crowded. The brief entries in his diary record the composition of various symphonies, and he seems to have travelled a great deal over the north of England. In 1761 he applied for an important post in Edinburgh—"the manager of the concerts intending to leave that place"—and in anticipation of receiving the appointment, he terminated his engagement with Lord Darlington. However, Herschel was disappointed, as the concert manager altered his plans and decided to remain at his post. On arriving in Edinburgh, he records in his diary: "I was introduced to Mr. Hume, the metaphysician, and a few days after, at one of their regular concerts, I was appointed to lead the band of musicians, while some of my symphonies and solo concerts were performed. Mr. Hume, who patronised my performance, asked me to dine with him, and accepting of his invitation, I met a considerable company."

During the next few months, Herschel held temporary appointments at Newcastle and Pontefract, and in April, 1762, he accepted a post as manager of concerts at Leeds, where he remained for about four years. During this time, his public engagements multiplied, and he was rapidly acquiring a notable position as a teacher

of music—in which he was greatly aided by his friend, Dr. Miller, organist at Doncaster, who advised him to compete for the post of organist at Halifax. In his memorandum for 7th March, 1766, Herschel states that the "Messiah" was performed at a private club of chorus singers in Halifax, where it was agreed to rehearse the same oratorio every other Friday in order to perform it in the church at the opening of a new organ erected there. ". . . I was a candidate for the place of organist, which, by the interest of the Messrs. Bates and many musical families I attended, I had great hopes to obtain". On 30th August, 1766, he was unanimously chosen as organist, but he had already been asked to allow himself to be nominated as organist of the Octagon Chapel at Bath, where a new organ was in process of erection. On 30th November, he played the organ at Halifax for the last time, and notes: "For the thirteen Sundays of my being organist, I was paid thirteen guineas". On 9th December he arrived at Bath; and on 4th October, 1767, the Octagon Chapel was opened, with Herschel as organist. He now entered on a busy and successful musical career. Pupils flocked to him, and sometimes his lessons numbered thirty-five a week. In addition, he composed anthems and psalm-tunes. Under the date 28th March, 1767, he noted, "Taken a house from 25th March to 29th September in Beaufort Square". Herschel had at last a settled home in England.

In his diary, under the date 5th April, Herschel notes: "Went into mourning for the death of my father". The vicissitudes through which the family passed have been graphically described by Caroline, who was, at her father's death, a girl of seventeen. From her earliest years, Caroline had two objects of idolatry—her father and her "dear brother William"—"the best and dearest of brothers". Her mother was unimaginative and unsympathetic, without interest in intellectual or

graceful accomplishments. "It was her certain belief," Caroline records, "that my brother William would have returned to his country and my eldest brother not have looked so high if they had had a little less learning." Accordingly, Caroline became virtually the Cinderella of the family—from earliest years a little neglected maid-of-all-work. Her eldest brother and sister showed her little attention, and all her love was concentrated on the father who wished to give her "something like a polished education," and on her brother William, who invariably showed her kindness and affection.

After her father's death, she describes herself as having fallen into a "state of stupefaction". She "could not help feeling troubled about her future destiny". Her mother and her brother Jacob consistently under-estimated her; and domestic service seemed to be the only future in store for her. But William had not forgotten the little sister of early years. In 1771 he wrote home proposing that she should join him in Bath and become "a useful singer for his winter concerts and oratorios". Despite the opposition of her mother and the ridicule of her brother Jacob, the plan materialised. In the autumn of 1772 William Herschel arrived in Hanover, and at the close of a fortnight's stay, set off for England along with Caroline. They arrived in Bath on 28th August, 1772, and Caroline was at once installed as her brother's housekeeper. She received instruction in English and arithmetic as well as lessons in music. Already, too, a new interest had crept into Herschel's life. "By way of relaxation," his sister tells us, "we talked of astronomy and the bright constellations with which I had made acquaintance during the fine nights we spent on the Postwagen travelling through Holland."

CHAPTER II.

HERSCHEL AS AMATEUR ASTRONOMER.

IN his diary, under the date 1766, Herschel has the following entries: "February 19th. Wheatley. Observation of Venus." "February 24th. Eclipse of the Moon at 7 o'clock a.m. Kirby." These are the first indications of his interest in astronomy. He had from early years inherited from his father a taste for what might be called star-gazing, and along with this he had had from youth a bent towards mathematical as well as philosophical research. Even in his busiest years, he never ceased to read and study in his leisure hours. During the first years of his stay in England, his foremost care was to master the English language. Next he acquired Italian, which he believed to be essential to his profession. From this he passed on to the study of Latin and Greek. The latter language, however, he dropped, "as leading me too far from my other favourite studies by taking up too much of my leisure. The theory of music being connected with mathematics induced me very early to read in Germany all that had been written upon the subject of harmony; and when, not long after my arrival in England, the valuable book of Dr. Smith's 'Harmonics' came into my hands, I perceived my ignorance, and had recourse to other authors for information, by which I was drawn on from one branch of mathematics to another." After perusing Smith's "Harmonics," he became possessed of a copy of the same author's "System of Optics". The study of optics passed into that of astronomy, which

was stimulated by "Astronomy Explained upon Sir Isaac Newton's Principles," by James Ferguson, the Scottish astronomer. Herschel's early interest in the latter science seems to have been revived. So enthusiastic did he become that, in his own words, "I resolved to take nothing upon trust, but to see with my own eyes all that other men had seen before". At the time of his sister's arrival at Bath, Herschel had plunged in earnest into the study of astronomy. "He went to sleep," she tells us, "buried under his favourite authors; and his first thoughts on rising were how to obtain instruments for viewing these objects himself of which he had been reading." In May, 1773, he procured some object-glasses which he fitted into pasteboard tables. Caroline Herschel, who at that time had no interest whatever in telescopic astronomy, tells us: "I was much hindered in my musical practice by my help being continually wanted in the execution of the various contrivances, and I had to amuse myself with making the tube of pasteboard for the glasses which were to arrive from London". At length, Herschel completed this instrument, 4 feet long, which magnified forty times. With this, he records, he observed Jupiter and its satellites. Afterwards he made other two refractors—15 and 30 feet long respectively. Herschel soon discovered for himself the great weakness of the refracting telescope—the long tubes which were then necessary in order to counteract the effect of chromatic aberration. Finding the long tubes almost "impossible to manage," he turned his attention to the reflecting telescope, and in September hired a two-foot Gregorian reflector, which he found much more convenient. He decided to acquire a mirror of his own, for a tube 5 or 6 feet long. On enquiry he found there were none in the market of so large a size. "A person," his sister tells us, "offered to make one at a price much above what my brother thought proper to give." Herschel, however, was not discouraged. He

became acquainted with a Quaker resident in Bath, who had in his leisure hours amused himself with efforts at the construction of mirrors. This individual had apparently failed in his endeavours—"his knowledge," Herschel noted, in that indifferent English which characterised him throughout his lifetime, "being very confined"—and had decided to dispose of his tools and half-finished mirrors. Herschel accordingly purchased his stock, and plunged at once into the work of telescope-making.

All through the winter 1773-4 and the following spring and summer, Herschel laboured at his new line of work, in the midst of his busy professional life. By 21st October, he had succeeded in casting mirrors for a two-foot reflector, and by the middle of December, "it became necessary to think of mounting these mirrors". Early in the new year, he placed a $5\frac{1}{2}$-foot mirror into a square wooden tube, but finding the adjustment of the Gregorian telescope very troublesome, he decided to have recourse to the Newtonian form. On 1st March, 1774, he made his first entry in his astronomical journal, stating that he had viewed "the lucid spot in Orion's sword belt" and the ring of Saturn, which appeared "like two slender arms". The success of this instrument encouraged Herschel to construct other telescopes of the Newtonian form, and at length he succeeded in making a 7-foot telescope with "many different object mirrors". On 1st May, 1776, he observed Saturn's ring and two belts "with great perfection".

The memoirs of his sister give us some idea of his unflagging energy. With sorrow, natural from the housekeeper's point of view, Caroline saw almost every room in the house transformed into a workshop. A tube and stand were set up in a handsomely-furnished drawing-room; while Alexander Herschel, the younger brother, who had now come to reside in Bath, erected a huge turning-machine in a bedroom, for turning eye-pieces

and grinding glasses. "Every leisure moment was eagerly snatched at for resuming some work which was in progress, without taking time for changing dress, and many a lace ruffle was torn or bespattered by molten pitch." From now onwards, Caroline proved herself the devoted assistant and helper of her brother, keeping house for him, assisting him in music and in his work of telescope-making. "By way of keeping him alive," she says, "I was constantly obliged to feed him by putting the victuals by bits into his mouth". This was once the case when, in order to finish a seven-foot mirror, he had not taken his hands from it for sixteen hours together. "In general he was never unemployed at meals, but was always at those times contriving or making drawings of whatever came in his mind. Generally I was obliged to read to him whilst he was at the turning lathe or polishing mirrors, 'Don Quixote,' 'Arabian Nights' Entertainments,' the novels of Sterne, Fielding, etc.; serving tea and supper without interrupting the work with which he was engaged. . . . and sometimes lending a hand. . . . My brother Alex. was absent from Bath for some months every summer, but when at home he took much pleasure to execute some turning or clockmaker's work for his brother."

Herschel was not content with the construction of one or two telescopes. The work went on during the remainder of his stay in Bath. How he contrived to continue the construction of telescopes while making long-continued surveys of the heavens—all in the spare time which he was able to snatch from his busy career as a professional musician—must always remain more or less of a mystery.

His earliest observations were on the Moon and planets. In 1776 he made a number of examinations of the lunar surface, and three years later was engaged in measuring the heights of the lunar mountains. From 1774 onwards, he carefully observed Saturn, and in

April, 1777, he commenced to make sketches in pen and ink of the markings on the surface of Mars, and in the following year of those on Jupiter. His attention was not confined to the members of the Solar System, and in 1777 he commenced a series of observations on the variable star, Omicron—or Mira—Ceti. As early as 1778 he had conceived the idea of attempting to determine by measures of close doubles the annual parallax or apparent displacement of a star in the sky due to the earth's change of position as it moves in its orbit. From this parallax, the distance of a star is determined. Before Herschel's time, astronomers had made many attempts to measure stellar parallax, but owing to the great distance of even the nearest stars and the consequent smallness of the displacement, and also because of the comparative imperfection of astronomical instruments, all these efforts had failed. Herschel was particularly interested in the problem, and made several attempts to solve it, but was unsuccessful. It was not until 1838 that the first determinations of stellar parallax were made. Herschel's attempts were not altogether in vain, however, for while tackling the problem, he was led to the study of double stars, which resulted, after many years, in one of his greatest discoveries. At the same time he executed his first review of the heavens with his 7-foot Newtonian reflector. The review only extended to the first four magnitudes: it was in itself a mere beginning, but it was the starting-point of his work on stellar distribution.

Herschel soon became known to the cultured public of Bath, not only as a prominent musician, but also as an amateur astronomer of considerable eminence. His introduction to literary and scientific circles in the town was a somewhat unconventional one. In his diary, under the date December, 1779, there occurs the following entry: "About the latter end of this month, I happened to be engaged on a series of observations on

the lunar mountains, and the Moon being in front of my house late in the evening, I brought my 7-foot reflector into the street, and directed it to the object of my observations. While I was looking into the telescope, a gentleman coming by the place where I was stationed stopped to look at the instrument. When I took my eye off the telescope, he very politely asked if he might be permitted to look in, and expressed great satisfaction at the view. Next morning, the gentleman, who proved to be Dr. Watson, jun. (now Sir William), called at my house to thank me for my civility in showing him the Moon, and told me that there was a Literary Society then forming at Bath and invited me to become a member, to which I readily consented."

About the middle of January, 1780, this society—the Philosophical Society of Bath — began its meetings. Herschel not only attended these, but contributed a considerable number of papers—thirty-one in all—in the course of the next two years. One or two of these dealt with astronomical subjects, such as the height of the lunar mountains, and the variable star Mira Ceti; but most of them were on metaphysical and physical subjects, such as "The Utility of Speculative Enquiries," "On the Existence of Space," and "Experiments in Light". These were nearly all published in 1912 in the "Collected Scientific Papers of Sir William Herschel". Through Dr. Watson's influence, Herschel was introduced to scientific circles in London, and he forwarded four communications to the Royal Society before he was elected a Fellow. These were, a paper on "Mira Ceti," read 11th May, 1780; on the "Mountains of the Moon," read the same day; on the "Rotation of the planets on their Axes, with a view to determine whether the Earth's diurnal motion is perfectly equable," —a remarkable and ingenious paper bearing the stamp of his own peculiar methods of investigation—read 11th January, 1781; and "Account of a Comet," read 26th April, 1781.

The last-named paper gave an account of the discovery which marked the turning-point in Herschel's career. On 17th August, 1779, he commenced his second review of the heavens. This review was made with his 7-foot telescope of 6·2 inches aperture, and included stars down to the eighth magnitude; its main purpose was to register double stars. On Tuesday, 13th March, 1781, in the course of this review, he jotted down in his journal the following note, in somewhat doubtful English: "In the quartile near Zeta Tauri, the lowest of two is a curious either nebulous star or perhaps a comet. A small star follows the comet at two-thirds of the field's distance." In the paper afterwards communicated to the Royal Society, he explained that he perceived a star which appeared "visibly larger than the rest: being struck with its uncommon magnitude, I compared it to H Geminorum and the small star in the quartile between Auriga and Gemini, and finding it so much larger than either of them, suspected it to be a comet". On Saturday, 17th March, he wrote, "I looked for the comet or nebulous star, and found that it is a comet, for it has changed its place". By Monday, the 19th, he found that the supposed comet "moves according to the order of the signs, and its orbit declines but little from the ecliptic".

The discovery was soon communicated to the Observatories of Greenwich and Oxford. Maskelyne, the Astronomer-Royal, wrote to Dr. Watson on the 4th April that he had observed the strange object, "very different from any comet I ever read any description of or saw". On 23rd April he wrote to Herschel: "It is as likely to be a regular planet moving in an orbit nearly circular round the Sun as a comet moving in a very eccentric ellipsis"; and he immediately notified the French astronomers of the discovery. Messier, the most famous observer of comets, commenced observations on 16th April, and his example was followed by Lalande,

Lemonnier, and other astronomers in France and by Bode in Germany. Efforts were made to calculate its orbit, on the assumption that it actually was a cometary body. Orbits were calculated by Méchain, De Saron, Laplace, and others. These efforts were fruitless. On 8th May De Saron announced that the "comet" was much more distant from the Sun than had been supposed. Laplace independently reached a similar conclusion. Meanwhile, Lexell, the St. Petersburg mathematician, who happened to be in England when the discovery was made, informed the St. Petersburg Academy that the object discovered by the Bath musician was probably not a comet at all, but an exterior planet, revolving at twice the distance of Saturn, thus confirming Maskelyne's sagacious surmise. Later it transpired that the planet had been observed no fewer than seventeen times between 1690 and 1781 by able observers such as Flamsteed, Bradley, Lemonnier, and Meyer, all of whom failed to differentiate it from an ordinary star, either in regard to its appearance or its motion. Lemonnier, indeed, had the discovery almost within his grasp, for he observed the planet on four consecutive days in January, 1769, but his carelessness robbed him of the distinction of detecting a new celestial body.

No little excitement was aroused by Herschel's achievement. It was the first planetary discovery within the memory of man—Mercury, Venus, Mars, Jupiter, and Saturn having been known from prehistoric times. More wonderful still, the discovery had been made, not by the leading astronomers of the day, but by an unknown amateur. At one bound Herschel leaped from obscurity to fame. The Royal Society of London awarded him the Copley Medal in November, 1781, and elected him a Fellow in December, exempting him from payment of subscriptions, as a mark of esteem. The discovery had caused a stir in still higher circles, and on 10th May, 1782, Herschel was informed that the King—

George III—expected to make his acquaintance. On 8th May he left Bath to join his friend, Dr. Watson, at Lincoln's Inn Fields, taking with him his instruments, star-catalogues, maps, tables, etc. In a letter to his sister, dated 25th May, he stated that he had had an audience of the King, to whom he presented a drawing of the Solar System. On 2nd July Herschel noted in his diary: "I had the honour of showing the King and Queen and the Royal Family the planets Jupiter and Saturn, and other objects".

Herschel was now seriously considering the possibility of abandoning the profession of music and devoting himself to astronomy. There can be little doubt that after George III expressed interest in the discovery, Herschel indicated that he was anxious to be made "independent of music". The result of his interview with the King was his appointment as King's Astronomer. The appointment is referred to by Herschel himself in his journal in the following terms: "It was settled by His Majesty that I should give up my musical profession and, settling somewhere in the neighbourhood of Windsor, devote my time to astronomy". The salary attached to the new office was fixed at £200—certainly not a large sum. Indeed, when Herschel's intimate friend, Dr. Watson, was informed as to the exact amount, he exclaimed, "Never bought monarch honour so cheap". Writing to her nephew, Sir John Herschel, in April, 1827, Caroline attributed the "close bargains" made between George III and her brother to the "shabby, mean-spirited advisers" of the King. Undoubtedly Herschel made a pecuniary sacrifice in accepting the offer, but 'the prospect of entering again on the toils of teaching, etc," his sister tells us, "which awaited my brother at home, appeared to him an intolerable waste of time". Doubtless Herschel believed it to be the best policy to close with the King's offer and thus be free to devote himself to the study which had become the master-

passion of his life. The meagreness of the allowance has been often commented upon, but it must be remembered, in justice to George III, that, firstly, the purchasing power of money was considerably greater then than now, and, secondly, the regular duties attached to the office were at that time very few. There is no doubt that George III, by his creation of this new post, made possible Herschel's long career of investigation and discovery: for no man, not even Herschel, could possibly have stood the strain of a life of professional activity and scientific investigation combined. As one of his biographers has well said, "The astronomer of Slough was the gift to science of the poor mad king".

CHAPTER III.

HERSCHEL AS PROFESSIONAL ASTRONOMER.

ON 1st August, 1782, William and Caroline Herschel, in accordance with the obligation of the holder of the new office of King's Astronomer to reside near Windsor, entered into occupation of a large house on Datchet Common. The house was in a ruinous condition and the garden and grounds were overgrown with weeds. Nevertheless there were, in Herschel's eyes, compensating advantages. There were outhouses available for the work of telescope-making; a large laundry capable of refitting as a library; and, most important of all, a grass lawn where telescopes could be erected. Despite the discomforts of the half-ruinous house, and the separation from congenial friendships—most of all from Alexander Herschel, who remained in Bath to continue his musical career—William Herschel was in the best of health and spirits. "Much of my brother's time," Caroline Herschel records, "was taken up in going when the evenings were clear to the Queen's Lodge to show the King, etc., objects through the seven-foot". Undoubtedly there was much exacting and irksome duty of this kind, of which Caroline complains in her reminiscences again and again. Yet despite this, and despite also the smallness of his salary, Herschel always expressed gratitude for the King's generosity. The personal relations between George III and his astronomer seem to have been consistently congenial; and one cannot help feeling that something more than expediency

prompted Herschel in his choice of a name for the new planet which he had discovered.

As early as May, 1782—before the King had appointed him as King's Astronomer—Herschel was apparently of opinion that the new planet should be named after George III. In a letter to Herschel, dated 10th May, 1782, Colonel Walsh, evidently one in close touch with the court, wrote: "In a conversation which I had the honour to hold with His Majesty on 30th ult. concerning you and your memorable discovery of a new planet, I took occasion to mention that you had a two-fold claim as a native of Hanover and a resident of Great Britain, where the discovery was made, to be permitted to name the planet from His Majesty". In a letter to his friend Watson in July, Herschel suggested the name, "Sidus Georginum". It was not until the following year, after he was settled at Datchet, that Herschel addressed to Sir Joseph Banks, President of the Royal Society, a letter concerning the name of the new planet. "In the fabulous ages of ancient times," he said in the course of this letter, "the appellations of Mercury, Venus, Mars, Jupiter, and Saturn were given to the planets as being the names of their principal heroes and divinities. In the present more philosophical era, it would hardly be allowable to have recourse to the same method and to call on Juno, Pallas, Apollo or Minerva for a name to our new heavenly body. The first consideration in any particular event or remarkable incident seems to be its chronology: if, in any future age, it should be asked *when* this last-found planet was discovered, it would be a very satisfactory answer to say, 'In the reign of King George the Third'. As a philosopher, then, the name of Georgium Sidus presents itself to me as an appellation which will conveniently convey the information of the time and country where and when it was brought to view." Herschel then proceeds to eulogise the King as "the liberal protector of every art and

science," and as his own benefactor, and closes with these words: "By addressing this letter to you, Sir, as President of the Royal Society, I take the most effectual method of communicating that name to the Literati of Europe, which I hope they will receive with pleasure".

Herschel's suggestion, however, did not meet with the approval of the scientific world. As the late Sir Robert Ball happily expressed it, the continental astronomers thought that the King of England would "seem oddly associated with Jupiter and Saturn; perhaps also they considered that the British dominions, on which the Sun never sets, were already quite large enough without further extension to the celestial regions". Lalande proposed the name of Herschel, and for a considerable time the planet was thus known in France. Indeed the name was also adopted in many circles in Great Britain. Bode of Berlin, the editor of the "Astronomisches Jahrbuch" of the day and one of the leading German astronomers, suggested "Uranus," in keeping with the old custom of affixing mythological names to the celestial bodies. For years all three names were in use. In the "Nautical Almanac" the name, "the Georgian," evidently preferred to "Georgium Sidus," was used officially until 1847. By the middle of the century, however, the name "Uranus" had been generally adopted, and there can be no doubt that the decision was sound. Bode was right and Herschel wrong.

We can hardly suppress a feeling of regret that Herschel, with his great mind and soul, could have made a suggestion which savoured of sycophancy: but we must bear in mind the circumstances. No planetary discoveries had been made since prehistoric times, and there was something to be said for making a new departure. That Herschel's suggestion was not made solely out of gratitude is obvious from the fact that he had practically decided on the name before he was appointed to the new office. As a matter of fact, Herschel seems

to have undoubtedly had for the King a high personal regard. They were both Hanoverians, and thus there was a sentimental tie between them: and George III., whatever condemnation we may pass on him as a monarch, seems undoubtedly to have taken an intelligent interest in astronomy. In his early days he had made observations at the private observatory at Kew. That he did take an intelligent interest is obvious from a letter which Herschel wrote on 20th May, 1787, to an official at Windsor Castle, in which he requested him to inform the King of the luminosity of a lunar crater, adding that he would himself be at Windsor in the evening to see the King's 10-foot telescope set up for observation.

Despite Herschel's own friendship for the King and his own silence as to the smallness of his salary, there can be no doubt that he was at first sorely handicapped by straitened circumstances. He had made a great financial sacrifice in accepting the post of King's Astronomer. Had he been able to avoid incurring expenses, he could have managed to live on £200 a year; but it was imperative for him to construct larger instruments, and the instruments which he had were in constant need of repair and readjustment. His salary, as has been well said by the late Miss Clerke, "gave him the means of living, but not of observing as he proposed to observe". Accordingly he plunged with enthusiasm into the work of making telescopes for sale. "The goodness of my telescopes," he wrote in his journal, "being already known, I was desired by the King to get some made for those who wished to have them. . . . This business in the end not only proved very lucrative, but also enabled me to make extensive experiments for polishing mirrors by machinery."

Despite the strenuous work of telescope-making, Herschel, while at Datchet, continued his nightly surveys of the sky. His third review of the heavens, which had been commenced at Bath, was completed in January,

1784. This review included all the stars of Flamsteed's catalogue and the small stars near them. The work was carried through with amazing rapidity. He would observe for ten or twelve hours at a stretch, and as many as 400 stars were observed and measured in the course of a night. Later in the same year, his attention was drawn to star-clusters and nebulae by the appearance of Messier's famous catalogue, and accordingly on 28th October, 1783, he began to "sweep the heavens" for these objects with his new 20-foot reflector of 18·7 inches aperture, and at the same time to "gauge" the depth of the sidereal system. A number of experimental observations were made, and on 18th December he commenced his systematic "sweeps," which were continued till 1802.

In this work he found his sister an invaluable helper. In 1782, she tells us, her thoughts were "anything but cheerful". "I found I was to be trained as an assistant-astronomer, and by way of encouragement, a telescope adapted for 'sweeping,' consisting of a tube with two glasses, such as are commonly used in a 'finder' was given me. I was to 'sweep for comets'. . . . But it was not until the last two months of the same year that I felt the least encouragement to spend the star-light nights on a grass-plot covered with dew or hoar-frost without a human being near enough to be within call. . . . All these troubles were removed when I knew my brother to be at no great distance making observations with his various instruments, on double stars, planets, etc., and I could have his assistance immediately when I found a nebula, or cluster of stars, of which I intended to give a catalogue; but at the end of 1783 I had only marked fourteen, when my sweeping was interrupted by being employed to write down my brother's observations with the large 20-foot." Caroline's observations are preserved in three volumes of quarto and four of folio. These observations were at first not unattended by danger. They

were commenced when the mountings of the telescopes were in a very unfinished state, and Herschel was "elevated fifteen feet or more on a temporary cross-beam instead of a safe gallery". Caroline Herschel herself met with a somewhat severe accident on the last day of 1783, and she left it on record that the Italian astronomer Piazzi—discoverer of the first asteroid—"did not go home without getting broken shins by falling over the rack-bar".

By the summer of 1785, Herschel decided that the old house at Datchet was impossible as a permanent residence. An attack of ague was found to be due to its damp situation. Accordingly, early in June, the Herschels removed to a house at Clay Hall, near Old Windsor, where observations were at once commenced. But trouble arose with the landlady—"a litigious woman who refused to be bound to reasonable terms"—and in the following spring Herschel fixed upon a new home at Slough, near Windsor. Thither his instruments and apparatus were transported on 3rd April, 1786, without the loss of a single hour's observation. "The last night at Clay Hall," says Caroline, "was spent in sweeping till daylight and by the next evening the telescope stood ready for observation at Slough." This was the last removal. The remainder of Herschel's life was spent at Slough —"the spot of all the world," said Arago, "where the greatest number of discoveries have been made". Here for many years, Herschel and his devoted sister worked from twilight to dawn, sweeping for clusters and nebulae, counting the stars in limited regions of the heavens, occasionally scrutinising the Moon and the planets. "If it had not been," writes Caroline, "for the intervention of a cloudy or moonlit night, I know not when he or I either would have got any sleep." In the daytime, too, his activity was ceaseless. He had to attend to his telescopes and to direct the army of workmen who were constantly employed making repairs; in addition, he was

actively employed systematising his observations and co-ordinating his results, which appeared in the long series of papers contributed to the "Philosophical Transactions" of the Royal Society—collected and published in two volumes in 1912.

It soon became apparent that the work of making telescopes for other observers, though lucrative, was in many respects a waste of time. Herschel had long contemplated the construction of a very large telescope, but this was impossible so long as his spare time was given to the manufacture of smaller instruments, the great majority of which passed into the possession of royal or aristocratic dabblers in astronomy and were practically mere ornaments. A few, however, were supplied to continental astronomers. With a 7-foot, Schröter, the German astronomer, practically inaugurated the systematic study of the Moon's surface.

Caroline Herschel notes that it was her brother's chief object at this time to construct a 30 or 40-foot instrument, "for he was then on the wrong side of forty-five and felt how great an injustice he would be doing to himself and to the cause of astronomy by giving up his time to making telescopes for other observers". But nothing could be done without a grant from the King; Herschel could not bear the expense of constructing a great telescope for himself. After some preliminary spade-work had been done in the proper quarters by his life-long friend, Sir William Watson, Herschel requested Sir Joseph Banks, President of the Royal Society, to make application for a grant from the King. In September, 1785, a grant of £2000 was made, and preparations for the making of the instrument were at once begun. Two years later a second sum of £2000 was granted, and in addition Herschel received, over and above his salary, £200 per annum for the up-keep of the telescope; while a salary of £50 a year was bestowed on Caroline Herschel as her brother's assistant. By this time her name was

becoming famous in the world of science. On 1st August, 1786, during Herschel's absence in Germany, she discovered a comet, the first of eight similar objects to her credit. The small annuity conferred upon her was a recognition—painfully inadequate—of her own work in astronomical science.

The construction of the great telescope occupied nearly four years. The erection of this immense instrument took up a great deal of Herschel's attention. His sister asserted that "there is not one screwbolt about the whole apparatus but what was fixed under the immediate eye of my brother. I have seen him lie stretched many an hour in a burning sun, across the top beam while the iron-work for the various motions was being fixed. At one time, no fewer than twenty-four men (twelve and twelve relieving each other) kept polishing day and night; my brother, of course, never leaving them all the while, taking his food without allowing himself time to sit down to table."

This ceaseless industry bore fruit when in August, 1789, the great telescope was ready for use. Herschel's former telescopes had been Newtonians, with small secondary mirrors. In January, 1787, however, he made a novel experiment with his 20-foot telescope. In order to save the light lost by the second reflection, Herschel removed the small mirror and slightly tilted the tube. The result more than justified expectations, and the experiment resulted in the discovery of two satellites of Uranus. Accordingly, he decided to make the 40-foot telescope on this "front-view" principle. This particular form of the reflector is known as the Herschelian.

Herschel was very proud of his large telescope and in 1795 sent a description of it to the Royal Society. Yet, on the whole, its performances were disappointing. Immediately it was erected Herschel succeeded in con-

firming the existence of two new satellites of Saturn: and to the ringed planet he turned his great instrument on numerous occasions. But it was cumbersome and difficult to manipulate, and the speculum on which so much care had been bestowed preserved its original polish for no more than two years. In Herschel's later years, he rarely made use of it, although it remained standing until seventeen years after its maker's death. In 1839, it was dismantled by Sir John Herschel, and laid in a horizontal position, which it occupied for many years, until a falling tree destroyed all but ten feet of the tube.

The completion of the 40-foot was the climax of Herschel's career as a maker of telescopes. The fame of the great instrument spread over the world. Princes, dukes, and courtiers visited Slough in order to view one of the wonders of the age. Astronomers, too, came from all parts of the world—Lalande, Méchain, Legendre, Cassini from Paris, Oriani from Milan, Piazzi from Palermo, Sniadecki from Cracow. Slough became a place of pilgrimage, not only for astronomers, but also for large numbers who had only a slight interest in, or curiosity about, the science. Herschel did not abandon telescope-making altogether but it was not now so necessary for pecuniary reasons. On 8th May, 1788, Herschel was married to Mrs. Pitt, widow of John Pitt, Esq., and daughter of Mr. Adee Baldwin, a London merchant. Miss Burney, the novelist, has left on record her meeting with Herschel and his wife soon after the marriage. "His newly-married wife was with him, and his sister. His wife seems good-natured; she was rich, too! And astronomers are as able as other men to discern that gold can glitter as well as stars." Whether or not there is any ground for this hint as to a motive for Herschel's marriage, there can be no doubt that he was now relieved from all financial care. There can

be no doubt either that the marriage was a very happy one, and that the relations between his wife and his sister were all that could be desired. From this time onwards, however, Caroline Herschel resided in lodgings in the village of Slough.

In the earlier part of his career, Herschel rarely went from home except on business. On 3rd July, 1786, accompanied by his brother Alexander, he started for Göttingen, in order to convey to the University one of his 10-foot reflectors as a gift from George III. This was his last visit to his native country. In 1792, he made an extensive tour in England and Scotland, in the company of a Polish friend, General Komarzewski. Visits were paid to the principal factories in the middle and north of England, and Herschel seems to have taken a 7-foot telescope with him in order to treat his hosts to views of the heavens. The tour embraced Coventry, Birmingham—where he dined with James Watt—Bangor, Carnarvon, and Manchester, then via Liverpool, Preston and Carlisle to Glasgow. Here he received the freedom of the city and the degree of LL.D. from the University. From Glasgow the friends proceeded to Edinburgh, from whose University Herschel had received the same degree six years earlier. In Edinburgh he met numerous literary and scientific men, including Principal Robertson and Dr. Hutton, and, in addition, inspected the Observatory. The return journey was made by Sunderland, Durham and Richmond in Yorkshire.

At the close of the eighteenth century, Herschel was at the zenith of his powers and at the height of his prosperity. Honorary degrees were conferred upon him and learned societies enrolled his name among their members. He accepted these recognitions of his genius, but put little stress upon them. Miss Burney, who along with her father visited him on numerous occasions, described Herschel as "perfectly unassuming, yet openly

happy, and happy in the success of those studies which would render a mind less excellently formed presumptuous and arrogant. The King has not a happier subject than this man. . . . He seems a man without a wish that has its object in the terrestrial globe."

CHAPTER IV.

SOLAR AND PLANETARY STUDIES.

ONE result of Herschel's fame as the founder of stellar astronomy has been that his greatness as an observer and student of the Sun and planets has been largely overlooked. Nevertheless his work in solar and planetary astronomy alone would have gained for him the highest position among the astronomical observers of the day. "Among the celestial bodies," he wrote in 1799, "the Sun is certainly the first which should attract our notice." From an early date he was attracted by solar phenomena, and in the course of his career contributed several papers on the Sun to the Royal Society. In the first of these, "On the Nature and Construction of the Sun and Fixed Stars," read 18th December, 1794, he propounded his hypothesis of the Sun's constitution, to which he adhered throughout his lifetime.

Before Herschel's time, the Sun had been observed by Galileo, Scheiner, Fabricius, Hevelius, Cassini and others. Sun-spots had been observed for over a century and a half and many important details had been detected, but concerning their nature controversy had raged and uncertainty prevailed. In 1774, just at the beginning of Herschel's career as an observer, the well-known theory of sun-spots was propounded by Alexander Wilson, Professor of Astronomy in the University of Glasgow. A series of observations convinced him that the spots were depressions beneath the general surface of the Sun; not mountains, as many observers had supposed, but cavities in the glowing surface through which the darker

interior was visible. "Is it not reasonable," he asked, "to think that the great and stupendous body of the Sun is made up of two kinds of matter, very different in their qualities: that by far the greater part is solid and dark and that this immense and dark globe is encompassed with a thin covering of that resplendent substance from which the Sun would seem to derive the whole of his revivifying heat and energy?" Herschel's earliest observations were confirmatory of Wilson's conclusions. In 1783 he closely followed a large spot, noticing that "it was plainly depressed below the surface of the Sun: and that it had very broad shelving sides". He was soon led to adopt Wilson's view of the solar constitution, which he developed in his first paper on the Sun in 1794.

His observations of the great spot of 1774 led him to conclude that he viewed "the real solid body of the Sun itself, of which we rarely see more than its shining atmosphere." This interpretation of sun-spot observations was the foundation-stone of his theoretical edifice. He concluded, in agreement with, but independently of, Wilson, that the solar globe was dark and solid, surrounded by a glowing atmosphere composed of various "elastic fluids that are more or less lucid and transparent". This lucid fluid, named by Schröter the "photosphere," Herschel believed to be generated in the Sun's atmosphere. An analogy, he said, might be drawn from the generation of clouds in the terrestrial atmosphere. In his paper of 1801, Herschel concluded that there are "two different regions of solar clouds, like those upon our globe. In that case their light is only the uniform reflection of the surrounding superior self-luminous region."

"The solid body of the Sun beneath these clouds," Herschel said, "appears to be nothing else than a very eminent, large and lucid planet, evidently the first, or in strictness of speaking, the only primary one of our systems; all others being truly secondary to it." This

solid body, he believed to be protected from the great heat of the elastic fluid of its own atmosphere by dense planetary clouds; it was diversified by mountains and valleys, and was in every way analagous to the Earth and the other planets. "We need not hesitate to admit," he said in 1794, "that the Sun is richly stored with inhabitants." In 1801, after further close study, he claimed that all his former arguments had been confirmed.

Herschel's theory met with general acceptance for many years. It harmonised with the trend of later eighteenth century thought, which—possibly as a result of the reaction from narrow theological views of the Earth's supreme place in nature—shrank from the idea of empty worlds. It was not until the invention of the spectroscope that the theory was universally abandoned. Untenable though it was, it was the first serious attempt to co-ordinate the isolated facts ascertained concerning phenomena of the solar disc.

The fallacious nature of his theory should not blind us to Herschel's great work as an observer of solar phenomena. In his paper of 1794 he noted the existence of "elevated bright places" which, after Hevelius, he named faculae. "I see these faculae extended . . . over about one-sixth part of the Sun. . . . Towards the north and south I see no faculae; there is all over the Sun a great unevenness in the surface, which has the appearance of a mixture of small points of an unequal light; but they are evidently an unevenness or roughness of high and low parts." Very few details of the solar surface escaped his persistent scrutiny. His paper of 1801 described the process of spot-formation with a wonderful accuracy of detail. Curiously enough, Herschel—although he devoted attention to the prevalence or absence of spots—failed to notice the sun-spot period. Probably he would have done so, had his attention to the Sun been more exclusive.

Herschel's solar work was not purely telescopic. His investigations on light and heat occupied a great deal of

his time at the beginning of the century; and he contributed to the Royal Society on these subjects four papers in rapid succession. He was led to the inquiry by his search for the most suitable dark glasses for solar observation, in the course of which he found that some materials were opaque to light and others to heat. His papers have been called "the first exposition worth mentioning of the principles of radiant heat". In this exposition he showed that radiant heat obeyed the laws of reflection, refraction and dispersion. His investigation of the infra-red heat rays led to one of his greatest discoveries—that of the invisible portions of the solar spectrum.

Early in his career, Herschel paid considerable attention to the Moon. His second paper in 1780 dealt with his measures of the height of the lunar mountains. In 1783 a sensation was caused in scientific circles by the news that Herschel had seen lunar volcanoes in violent eruption. In a letter to Magellan, a Portuguese amateur astronomer, he stated that on 4th May, he "perceived in the dark part of the Moon a luminous spot. It had the appearance of a red star of about the fourth magnitude." In 1787 he communicated a paper to the Royal Society, in which he announced the appearance of other three volcanoes, and in which he promised the Society an account of the eruption of 4th May, 1783. This account was never forthcoming. The leading French astronomers were inclined to the view that the appearances were actually due to earth-shine. It is possible that Lalande, who visited Slough in 1788, may have converted Herschel to this view. At all events, nothing further was published concerning the supposed volcanoes.

Herschel believed the Moon to be both habitable and inhabited. Yet he laid it down in 1794 "that we perceive no large seas in the Moon, that its atmosphere (the existence of which has even been doubted by many) is extremely rare and unfit for the purposes of animal

life; that its climates, its seasons, and the length of its days totally differ from ours; that without dense clouds (which the Moon has not) there can be no rain; perhaps no rivers, no lakes". His belief in the habitability of our satellite arose from the view that its inhabitants "are fitted to their conditions as well as we on this globe are to ours".

Of the planets, Mercury alone was neglected by Herschel; he studied it only when in transit across the solar disc. His observations on Venus—"an object," he said, "that has long engaged my particular attention" —were commenced in April, 1777, and were continued for sixteen years. Herschel had four objects in view—to measure the rotation period of the planet, to ascertain the presence or absence of an atmosphere, to determine accurately the planet's diameter, and to give "attention to the construction of the planet with regard to permanent appearances". He satisfied himself that Venus did rotate, but the diurnal motion, he said, "on account of the density of the atmosphere of this planet, has still eluded my constant attention, as far as concerns its period and direction". The spots which Herschel discovered on the planet's surface were faint and ill-defined. His observations on Venus were in direct contradiction to those of Schröter. The German astronomer had not only estimated the planet's rotation period at 23½ hours, but had announced the existence of mountains on Venus, whose height exceeded five or six times the perpendicular elevation of Chimborazo. "As to the mountains on Venus," said Herschel, "I may venture to say that no eye which is not considerably better than mine, or assisted by much better instruments, will ever get a sight of them." Herschel's negative conclusions have been on the whole confirmed by later astronomers.

Herschel may be safely called the founder of Martian astronomy. In 1777 he commenced observations on Mars, and he early satisfied himself that "the constant

and determined shape" of the spots "as well as remarkable colour, show them to be permanent and fastened to the body of the planet". The spots which chiefly attracted his attention were the white polar caps. On 17th April, 1777, he noted, "There are two remarkable bright spots on Mars". These spots had been noticed by Maraldi early in the century, but Herschel was the first to investigate their nature and to chronicle their periodical variation in size. "I may well be permitted to surmise," he wrote in 1784, ". . . that the bright polar spots are owing to the vivid reflection of light from frozen regions; and that the reduction of these spots is to be ascribed to their being exposed to the Sun. In the year 1781, the south polar spot was extremely large, which we might well expect, since that pole had but lately been involved in a whole twelve months' darkness and absence of the Sun: but in 1783 I found it considerably smaller than before." Herschel's sagacious surmise has been abundantly confirmed by all subsequent observers. In addition, he determined the rotation period with considerable accuracy. In 1781 he announced it to be 24 hours, 39 minutes, 21·67 seconds; he also ascertained the axial inclination and equatorial diameter. The general conclusion which he reached as a result of his observations was that "the analogy between Mars and the Earth is, perhaps, by far the greatest in the whole solar system. Their diurnal motion is nearly the same; the obliquity of their respective ecliptics, on which the seasons depend, not very different." The planet, he concluded, "has a considerable but moderate atmosphere, so that its inhabitants probably enjoy a situation in many respects similar to ours".

The planet Jupiter did not claim so much of Herschel's attention as either Mars or Saturn. Nevertheless, his short study of the giant world marked an epoch. In his paper of 1781 on the "Rotation of the Planets round their Axes," he put forward as a suggested explanation

of the atmospheric condition of Jupiter what has been known as the "trade-wind" theory. "As the principal belts on Jupiter are equatorial, and as we have certain constant winds upon our planet that regularly, for certain periods, blow the same way, it is easily supposed that they may form equatorial belts by gathering together the vapours which swim in our atmosphere and carrying them about in the same direction. This will by analogy account for all the irregularities of Jupiter's revolutions." Herschel devoted no other paper to Jupiter, but in 1797 he communicated to the Royal Society his "Observations of the Satellites of Jupiter, with a Determination of their Rotation". From his determinations of their variable brightness, he concluded that the rotation periods of all four satellites coincided with their periods of revolution round Jupiter—a conclusion confirmed by subsequent research. Herschel also made the first attempt to measure the diameters of the satellites. His conclusion—also confirmed by later observers—was "that the third satellite is considerably larger than any of the rest; that the first is a little larger than the second and nearly of the size of the fourth; and that the second is a little smaller than the first or fourth or the smallest of them all".

"The planet Saturn," Herschel wrote, "is perhaps one of the most engaging objects that astronomy offers to our view. As such it drew my attention as early as the year 1774." And it received more of Herschel's attention than any of the other planets. Six of his papers to the Royal Society dealt with Saturn, the first in 1789 and the last in 1805. He concluded in 1789 that the planet had an atmosphere of considerable density; and from the appearance of the belts he inferred that it "turns upon an axis which is perpendicular to the ring," and this view was confirmed by his detection of a considerable polar flattening. In December, 1793, he stated that the period of rotation "is probably not of a long

duration"; and in the following year he confirmed his suspicion, and announced the period of rotation as 10 hours 16 minutes.

Five satellites of Saturn were known when Herschel commenced his study of the planet. His discovery of two exceedingly faint inner satellites, rendered fainter still by their proximity to the bright disc and ring of Saturn, was the result of long and continued investigation. He had entertained "strong suspicions" of the existence of a sixth satellite for a considerable time; and on 19th August, 1787, using the 20-foot reflector as a "front view," he noticed an object which he marked down as possibly a sixth moon. The possibility was rendered a certainty when on 28th August, 1789, he turned the new 40-foot on Saturn. Six satellites were manifestly visible, sharing in the planet's motion. On 17th September, he detected another satellite, still fainter, and closer to the ring, revolving in less than one terrestrial day. These moons were named Enceladus and Mimas. Two years later he announced that the fifth satellite—Japetus—performs its rotation, like the moons of Jupiter and our moon, in a period coincident with its revolution, These conclusions led him to an important generalisation, that "a certain uniform plan is carried on among the secondaries of our solar system; and we may conjecture that probably most of the moons of all the planets are governed by the same law".

The ring-system fascinated Herschel. In 1789 he suspected its division into two, and this suspicion was confirmed in 1791. "Its division into two very unequal parts can admit of no doubt." He appears to have seen the inner dusky or "crape" ring, but he did not recognise it as a portion of the system. In common with Laplace and contemporary astronomers, he believed the rings to be solid structures. In August, 1815, Herschel made his last observations of the planet, with both the 40-foot and the 20-foot telescopes.

As was to be expected, the planet Uranus was an object of special interest to its discoverer. In 1783 he communicated the results of his preliminary study of the new planet to the Royal Society. He then estimated that "the real diameter of the planet must be between four and five times that of the Earth". In a later paper, in 1788, he announced the diameter as 34,217 miles—a remarkably accurate measure. He commenced soon after the discovery to search for Uranian satellites. At first he was continually disappointed and gave over the attempt. Resuming his observations, however, with the front-view method, he detected on 11th January, 1787, two very faint stars. After careful search of these objects in motion he tells us that he deferred a final judgment as to their nature till 10th February. "And in order to put my theory of these two satellites to a trial, I made a sketch on paper to point out beforehand their situation with respect to the planet and its parallel of declination. The long-expected evening came on, and notwithstanding the most unfavourable appearance of dark weather, it cleared up at last, and the heavens now displayed the original of my drawing by showing in the situation I had delineated them, *the Georgian planet attended by two satellites.*"

He determined the times of revolution of these moons; estimated their size as probably not less than that of the satellites of Jupiter; and noted the great inclination of their orbits. In 1797 Herschel announced the discovery of four additional satellites, but this was never confirmed, and there can be little doubt that what he actually observed were small faint stars; although it is just possible that he may have glimpsed the very faint inner pair detected in 1847. A suspicion that Uranus was encircled by a ring similar to Saturn was finally negatived by his investigations in 1792, which he described as "very decisive against the existence of a ring".

Herschel never discovered a comet. This branch of

astronomy he left to his sister, who detected no fewer than eight during the course of her observing career. The first of these, discovered 1st August, 1786, was the subject of a short communication to the Royal Society. Other comets, too, seem to have been closely studied by him. The great comet of 1811 called forth a long communication to the Royal Society. In this paper, he emphasised the transient nature of comets.

Herschel missed discovering the first four asteroids, which were detected by Piazzi, Olbers and Harding, when the great astronomer of Slough was at the height of his powers as an observer. He closely studied them after their discovery and endeavoured to measure their discs, but his measures were not very exact. In a paper read before the Royal Society, on "Observations on the two lately discovered celestial bodies," he suggested the name "asteroids" for the new worlds. Brougham in the "Edinburgh Review" took exception to the name, and insinuated that Herschel had deliberately coined it for the purpose of keeping the discoveries of Piazzi and Olbers on a lower level than his own discovery of Uranus, Herschel made no direct reply to the attack. He merely referred to the fact that he had "incurred the illiberal criticism of the 'Edinburgh Review,'" and in 1804, in a subsequent paper on the asteroids, after the discovery of Juno, he said that "the specific difference between planets and asteroids appears now, by the addition of a third individual of the latter species, to be more fully established, and that circumstance, in my opinion, has added more to the ornament of our system than the discovery of another planet could have done".

CHAPTER V.

THE CONSTRUCTION OF THE HEAVENS.

"A KNOWLEDGE of the construction of the heavens," Herschel wrote in 1811, "has always been the ultimate object of my observations." All his other investigations —solar, planetary and stellar—were secondary to this great aim. Before the commencement of his career as an astronomer, the stars attracted very little attention. Star-catalogues had been formed, but, nevertheless, the stars were regarded chiefly as convenient reference-points for observations of the Moon and planets. A few double and variable stars and several star-clusters and nebulae had been discovered; theories of stellar distribution had been outlined by one or two obscure non-professional astronomers, such as Wright and Lambert. But there was little interest among astronomers in the study of the stars for their own sakes; and no great systematic effort had been made to discover the laws of stellar distribution and motion.

The field of sidereal astronomy, therefore, was virtually untrodden when, shortly after the beginning of his telescopic work, Herschel began his first review of the heavens. His second review, commenced in 1779, included stars down to the eighth magnitude. By-products of this review were the discovery of Uranus and the formation of his first catalogue of double stars. In December, 1781, he commenced his third review, which he completed in January, 1784, and which resulted in the publication of a second double-star catalogue. The prob-

lem which confronted Herschel was two-fold: (1) the scale, and (2) the structure of the stellar system. In 1781 he had written a paper on the parallaxes of the fixed stars, but his investigation only yielded a negative result. Accordingly he concentrated on the question of the structure of the universe and the arrangement of its component parts.

In 1783 the publication of Messier's first catalogue directed Herschel's attention to the star-clusters and nebulae. As soon as it came into his hands, he says, he applied his 20-feet reflector to the nebulae, "and saw with the greatest pleasure that most of the nebulae which I had an opportunity of examining in proper situations yielded to the force of my light and power and were resolved into stars". Accordingly, Herschel decided to "sweep" the heavens with two main objects in view: (1) to search systematically for new nebulae, and (2) to gauge the extent of the sidereal system by counting the number of stars visible in different regions of the heavens. In 1784, in his preliminary paper on the construction of the heavens, he described his method of star-gauging, which, he said, "consists in repeatedly taking the number of stars in ten fields of view of my reflector very near each other, and by adding their sums and cutting off one decimal on the right, a mean of the contents of the heavens, in all the parts which are thus gauged, is obtained".

In his paper on "The Construction of the Heavens," dated 1st January, 1785, Herschel gave the results of his preliminary investigations and outlined his theory of the stellar system. "That the Milky Way," he said, "is a most extensive stratum of stars of various sizes admits no longer of the least doubt, and that our Sun is actually one of the heavenly bodies belonging to it is evident. I have now viewed and gauged this shining zone in almost every direction, and find it composed of stars whose number, by the account of these gauges, constantly

increases and decreases in proportion to its apparent brightness to the naked eye." In the most crowded part of the Galaxy, Herschel occasionally counted as many as 588 stars in a field of view, and in quarter of an hour's time no fewer than 116,000 stars were thus enumerated, while other fields were almost destitute of stars. Herschel made two important assumptions—(1) that the stars were, roughly speaking, of the same size, and (2) that they were scattered throughout space with some approach to uniformity. As a result of his star-gauges, he was enabled on these two assumptions to estimate the possible extent and shape of the sidereal system. He sketched it as a cloven disc of irregular outline, extending much further in the direction of the Milky Way than in that of the galactic poles, the cleft representing the famous division in the Milky Way. The Milky Way was regarded as more or less an optical phenomenon, as a vastly extended portion of the stellar system.

Herschel's gauges led him to the view that the galactic system was strictly limited in extent. "It is true," he said, "that it would not be consistent confidently to affirm that we were on an island unless we had actually found ourselves everywhere bounded by the ocean, and therefore I will go no further than the gauges will authorise; but considering the little depth of the stratum in all those places which have been actually gauged, to which must be added all the intermediate parts that have been viewed and found to be much like the rest, there is but little room to expect a connection between our nebula and any of the neighbouring ones." The stellar system which he designated as "our nebula" was in his view an island universe—"a very extensive branching, compound congeries of many millions of stars". The majority of nebulæ and clusters he believed to be independent stellar units. He divided these nebulæ, or milky ways—for at this time the two terms were interchangeable in his

vocabulary—into four "forms," our "nebula" being regarded as of the third. In 1785 Herschel informed Miss Burney that he had discovered fifteen hundred universes,—"fifteen hundred whole sidereal systems, some of which might well outvie our Milky Way in grandeur".

Such was the famous "disc-theory" and its corollary —the hypothesis of island universes. For many years this theory was expounded in text-books of astronomy and popular science manuals as if it had been the outcome of Herschel's matured views on the stellar universe. The late R. A. Proctor, who was one of the first close students of Herschel's papers, truly remarked that "It seems to have been supposed that his papers could be treated as we might treat such a work as Sir J. Herschel's 'Outlines of Astronomy'; that extracts might be made from any part of any paper without reference to the position which the paper chanced to occupy in the entire series". The consequence of this method of expounding Herschel's views was that for many years astronomers were hardly aware of his gradual change of opinion.

The disc-theory and its corollary were, as already noted, based on the assumption of an equal scattering of stars in the Milky Way and involved the belief that all nebulæ were stellar clusters which would ultimately be resolved into stars. The first of these views was never held very confidently by Herschel. In his paper of 1785 he admitted that "in all probability there may not be two or three of them in the heavens, whose mutual distance shall be equal to that of any other two given stars, but it should be considered that when we take all the stars collectively there will be a mean distance which may be assumed as the general one". Even in the paper of 1785 Herschel remarked that it would not be difficult to point to two or three hundred gathering clusters in our system. Indeed, his classification of so-called "nebulæ" was based on his view that condensation

gave evidence of age. Accordingly, he foresaw, as a result of "clustering power," the breaking-up of the galactic system into many small independent nebulæ. More and more evidences of this "clustering power" came to his notice until in 1802 he said of the Galaxy: "This immense starry aggregation is by no means uniform. The stars of which it is composed are very unequally scattered and show evident marks of clustering together into many separate allotments." He was coming gradually to the view that the fundamental assumption underlying his disc-theory—that of an average equality of scattering—was untenable. In his paper of 1811 he said: "I must freely confess that by continuing my sweeps of the heavens, my opinion of the arrangement of the stars and their magnitudes and of some other particulars has undergone a gradual change; and, indeed, when the novelty of the subject is considered, we cannot be surprised that many things formerly taken for granted should, on examination, prove to be different from what they were generally but incautiously supposed to be. For instance, an equal scattering of stars may be admitted in certain calculations; but when we examine the Milky Way, or the closely-compressed clusters of stars, of which my catalogues have recorded so many instances, this supposed equality must be given up." With the abandonment of this general assumption, the disc-theory became untenable.

Herschel's daring attempt to formulate a cosmology proved abortive. In place of this he was led to evolve a cosmogony. He appears to have been unaware of Kant's nebular hypothesis; indeed, he seems to have had, at the beginning of his career, no conception of evolutionary development among the celestial bodies. The dim, misty-looking nebulæ were all believed to be external galaxies, which increased telescopic power could resolve into their component stars. He was led to question and then to reject this generalisation by his study of a

nebulous star of the eighth magnitude in the constellation Taurus, surrounded by a faintly-luminous atmosphere of considerable extent. The results of his investigations and reflections were contained in his remarkable paper "On nebulous stars properly so-called," dated 1st January, 1791. In regard to the nebulous star in Taurus, he said: "Our judgment will be that the nebulosity about the star is not of a starry nature". If, he pointed out, the nebulosity consisted of very remote stars, which appear nebulous on account of great distance, "then what must be the enormous size of the central point which outshines all the rest in so superlative a degree as to admit of no comparison?" If, however, the star is of average size, the smaller points composing the nebulosity must be almost infinitesimal. "We therefore either have a central body which is not a star, or have a star which is involved in a shining fluid of a nature totally unknown to us. I can adopt no other sentiment than the latter." And with characteristic caution he added in the same paper: "If therefore this matter is self-luminous, it seems more fit to produce a star by its condensation than to depend on the star for its existence".

This was in 1791, five years before Laplace suggested his classical hypothesis at the close of the "Systeme du Monde". The germ of the nebular theory, therefore, was present in the mind of Herschel at this early stage. In the paper of 1791, Herschel proceeded to apply his new view to the various nebulous regions all over the heavens. He concluded that he had been too hasty in his former surmise that all nebulæ were distant clusters. If the "shining fluid" can exist without stars, "we may with great facility explain that very extensive telescopic nebulosity" in the constellation Orion. "What a field of novelty is here opened to our conceptions!"

In 1802 Herschel dealt with the subject again in his "Catalogue of 500 new nebulæ". But it was not till

1811, in another epoch-making paper on the construction of the heavens, that Herschel enunciated his nebular hypothesis. In this paper he gave a complete list of nebulæ which he had discovered and studied, "assorting them into as many classes as will be required to produce the most gradual affinity between the individuals contained in any one class with those contained in that which precedes and that which follows it". Those contained in one class and those in the next class in order, he declared, have not so much difference between them, in his own suggestive remark, "as there would be in an annual description of the human figure, were it given from the birth of a child till he comes to be a man in his prime". He traced the evolutionary sequence from extensive diffused nebulosities, through irregular nebulæ, "nebulæ a little brighter in the middle," "nebulæ a little brighter" and "much brighter in the middle," nebulæ showing the progress of condensation, planetary nebulæ and stellar nebulæ, to "nebulæ nearly approaching to the appearance of stars". He declared it highly probable that "every succeeding state of the nebulous matter is the result of the action of gravitation upon it while in a foregoing one, and by such steps the successive condensation of it has been brought up to the planetary condition. From this the transit to the stellar form, it has been shown, requires but a very small additional compression of the nebulous matter." In 1814 he drew attention to double nebulæ joined by nebulosity between them. "It seems," he said, "as if we had these double objects in three different successive conditions: first as nebulæ; next as stars with remaining nebulosity; and lastly as stars completely free from nebulous appearance". Herschel's nebular hypothesis has never received in text-books of astronomy the attention it deserves. It was the result of long years of patient study, and is one of the most perfect examples of inductive reasoning in the history of science.

Herschel, as has been already remarked, had sought a cosmology and he had found a cosmogony. Nevertheless, he did not abandon his attempt to discover the structure of the sidereal system. In 1817 and 1818, when nearly eighty years of age, he communicated two remarkable papers to the Royal Society on the extent and condition of the Milky Way and on the relative distances of clusters of stars. In these papers Herschel explained his new method of star-gauging, which some writers have confused with his first. The two methods, however, were quite distinct. In the first, one telescope was used in different regions of the heavens; whereas in the second, various telescopes were turned on the same region. The new method assumed the distribution of the stars to approximate to a certain properly-modified equality of scattering, and also a certain equality of real brightness. In the paper of 1817 he applied this new principle to the Milky Way, and in the paper of 1818 to star-clusters, assuming that the relative distances of "globular and other clusters" can be determined by the telescopic powers necessary to reveal and resolve them, provided that the component stars are, generally speaking, comparable to Sirius in size. Proctor, writing in 1872, contended that "the principle is unsound and that Herschel himself would have abandoned it had he tested it earlier in his observing career". Most writers have agreed with his estimate: yet recent work on star-clusters[1] would seem to indicate that Herschel's second method was not so unsound as has been generally believed. Herschel propounded no hypothesis to take the place of the disc-theory. Indeed, his later view was that the sidereal system was much more extended in the plane of the Galaxy than he had previously believed. "The utmost stretch of the space-penetrating power of the 20-foot telescope could not fathom the profundity of the Milky Way." In 1817, he gave expression to the

[1] By Dr. Harlow Shapley, at Mount Wilson Observatory, California.

view that "not only our sun, but all the stars we can see with the eye are deeply immersed in the Milky Way and form a component part of it". Nevertheless, in the paper of 1818, he held that some of the nebulae, not obviously composed of true nebulous matter, which he called "ambiguous objects" are "clusters of stars in disguise, on account of their being so deeply immersed in space that none of the gauging powers of our telescopes have hitherto been able to reach them". Obviously, he still clung to the view that some of these dim, misty objects were "island universes".

The paper of 1818 was the last which Herschel wrote on the construction of the heavens. He failed in the object of his search, but countless others have failed since his day, and at the present time astronomers are still groping after the solution of the great problem. Herschel did not labour in vain: his papers on the structure of the universe form the foundation of all subsequent research. In the eloquent words of the late Miss Clerke: "One cannot reflect without amazement that the special life-task set himself by this struggling musician—originally a penniless deserter from the Hanoverian Guard—was nothing less than to search out the construction of the heavens. He did not accomplish it, for that was impossible; but he never relinquished it, and, in grappling with it, laid deep and sure the foundations of sidereal science."

CHAPTER VI.

STELLAR RESEARCHES.

HERSCHEL did not attain to the knowledge of the ultimate structure of the Universe to which he aspired; but in the course of his long career as an observer and thinker he was led to several discoveries of the greatest importance. The discovery of nebulæ was, of course, one of the objects of his long-continued series of "sweeps" of the heavens. He communicated his first catalogue of 1000 new nebulæ and clusters of stars to the Royal Society in 1788; this was followed three years later by a second catalogue of 1000 similar objects, while in 1802 he drew up a catalogue of 500 "new nebulæ, nebulous stars, planetary nebulæ and clusters of stars". He was equally devoted to the study of double stars. These objects, as already mentioned,[1] first attracted his attention because of their suitability for determination of relative stellar parallaxes. But Herschel soon realised that the measurement of the annual parallax of stars was beyond the power of his instruments. His quest for parallaxes from the study of double stars led him to another discovery altogether.

On 10th January, 1782, he communicated to the Royal Society a catalogue of 269 double stars, of which 227 had been discovered by himself; this was succeeded by a second list of 434 in December, 1784. From the beginning of his study of these stellar pairs, he seems to have had a suspicion as to their nature. In the postscript to his first catalogue he said: "In my opinion, it

[1] Chapter II., p. 19.

is much too soon to form any theories of small stars revolving round large ones". It was, of course, obvious that double stars might be optical only—caused by two stars happening to lie in the same line of vision. Nevertheless, despite his caution, he kept a careful watch on the relative positions of the components of double star systems for twenty years. In the paper accompanying his catalogue of 500 new nebulæ, read 1st July, 1802, Herschel expressed the view that "casual situations will not account for the multiplied phenomena of double stars," and announced that he was about to communicate a series of observations, from which it would be evident that "many of them have actually changed their situation with regard to each other, in a progressive course, denoting a periodical revolution round each other; and that the motion of some of them is direct, while that of others is retrograde". These observations were tabulated in two papers on "the changes that have happened in the relative situation of double stars," read in 1803 and 1804 respectively. In the first paper, Herschel brought forward evidence in regard to the orbital motions of Alpha Geminorum (Castor), Gamma Leonis, Epsilon Bootis, Zeta Herculis, Delta Serpentis, and Gamma Virginis. The second paper gave details concerning other fifty stars. Herschel also assigned periods to several of the more prominent binaries. These investigations, Herschel claimed, went to prove that many double stars are "not merely double in appearance, but must be allowed to be real binary combinations of two stars intimately held together by the bond of mutual attraction".

The importance of the discovery of binary stars may be realised when we recollect that previously there was no scientific proof of the prevalence of the law of gravitation outside of the Solar System. There were, of course, strong reasons for believing the law to be universal; and John Michell, a man of remarkable sagacity, had argued

before Herschel began his observations, that many double stars were certainly binaries. But there was no direct proof until Herschel, after twenty years of patient study, announced his results in 1802. The discovery gave scientific proof of the unity of the Cosmos and of the universal validity of the Newtonian law.

Another brilliant discovery, made almost casually, was announced in 1783 in a paper entitled "On the proper motion of the Sun and Solar System; with an account of several changes that have happened among the fixed stars since the time of Mr. Flamsteed". Halley had in 1718 announced that a number of the brighter stars, so far from being "fixed," in reality were moving through space with considerable velocity. Herschel gave it as his view that "there is not, in strictness of speaking, one fixed star in the heavens". "Now, if the proper motion of the stars in general be once admitted, who can refuse to allow that our Sun, with all its planets and comets, that is, the Solar System, is no less liable to such a general agitation as we find to obtain among all the rest of the celestial bodies?" The idea had occurred to several contemporary astronomers, Wilson, Lalande, and Mayer, but no one had succeeded in attacking the problem practically. It was plainly obvious that the motion of the Sun could only be detected through the resulting apparent motion of the stars, just as the orbital motion of the Earth is reflected in the planetary motions. If the Sun is moving in a certain direction, the stars in front will appear to disperse, while those behind will seem to draw closer together. But the problem is complicated by the individual motions of the stars; and these motions—themselves very minute—have to be decomposed into two parts, the real motions of the stars themselves and the apparent motion resulting from the translation of the Solar System. "We ought, therefore," said Herschel, "to resolve that which is common to all the stars, which are bound to have what is called a proper motion,

into a single real motion of the Solar System, as far as that will answer the known facts, and only to attribute to the proper motion of each particular star the deviations from the general law the stars seem to follow in those movements."

Herschel treated the problem in the simplest manner. Dealing with the proper motions of seven bright stars—Sirius, Castor, Procyon, Pollux, Regulus, Arcturus, and Altair—he separated their real from their apparent motions by simple geometrical methods, and reached the conclusion that the Solar System was moving towards a point in the constellation Hercules, the "apex" of the solar motion being marked by the star Lambda Herculis. "We may," he said, "in a general way estimate that the solar motion can certainly not be less than that which the Earth has in her annual orbit." In 1805, Herschel again attacked the problem, making use of Maskelyne's table of the proper motions of thirty-six stars. His result was in the main confirmatory of his earlier conclusions, the "apex" being again located in the constellation Hercules.

Herschel's brilliant discovery was regarded with considerable incredulity by several of his contemporaries and successors. They seemed to feel that the data on which he worked were too slender for a trustworthy result to be deduced. Bessel, the greatest practical astronomer of the next generation, maintained that there was no evidence in favour of a motion towards a point in Hercules; and even Sir John Herschel rejected his father's conclusions. In 1837, Argelander attacked the question from a study of the motion of 390 stars. The result of his investigation was to confirm abundantly Herschel's conclusions. Since Argelander's time, determination after determination has been made, by many illustrious mathematicians of each generation. Every refinement has been exhausted, "only," in the striking words of Ball, "to confirm the truth of that

splendid theory which seems to have been one of the flashes of Herschel's genius".

The light of the stars, no less than their motions, was a favourite subject of study with Herschel. His first communication to the Royal Society dealt with the famous variable star Mira Ceti; and several other papers dealt with the brilliancy of the stars. The problem of stellar variation fascinated him. "Dark spots, or large portions of the surface less luminous than the rest, turned alternately in certain directions, either towards or from us," he wrote in 1796, "will account for all the phenomena of periodical changes in the lustre of the stars so satisfactorily that we certainly need not look for any other cause." But he was aware of other variations—the gradual increase or decrease of the light of certain stars in the course of years or centuries. He regarded as a problem of great practical interest the stability or otherwise of the brilliance of the Sun. His interest in the question of stellar brightness and variation led to his determination of the relative brightness of the stars. Four catalogues of comparative brightness of stars were communicated to the Royal Society—the first on 25th February, 1796, the fourth on 21st February, 1799. The observations on which these catalogues were based were made in the years 1795-97, and Herschel seems to have attached so much importance to the work that for three years he discontinued his "sweeping" of the heavens. Two other catalogues were left unpublished at the time of his death, and were first issued in the collected edition of his works. The observations he himself described as "difficult and laborious". He mentioned in the paper accompanying his first catalogue the various causes of error which had to be guarded against, such as moonlight, the different altitudes at which a star might be viewed, the uncertainty of flying cloud, the scintillation of the stars, the zodiacal light, the aurora borealis, and "dew or damp upon the glasses or specula when a

telescope is used". Nevertheless, Herschel completed his catalogues, and left behind him a work of imperishable value. For a hundred years the work was under-estimated by astronomers, until, at the close of the nineteenth century, the catalogues were reduced and discussed by the late Professor E. C. Pickering, of Harvard, who gave the following estimate of the value of Herschel's work: "Herschel furnished observations of nearly 3000 stars, from which their magnitudes a hundred years ago can now be determined with an accuracy approaching that of the best modern catalogues. The average difference from the photometric catalogues is only ± 0·16, which includes the actual variations of the stars during a century, as well as the errors of both catalogues. The error of a single comparison but little exceeds a tenth of a magnitude."

Herschel's observations of starlight were not only visual and telescopic. In 1798 he passed the light of a few stars of the first magnitude through a prism applied to the eye-glasses of his reflectors. He found that the light of Sirius consisted of red, orange, yellow, green, blue, purple, and violet: that Betelgeux contained the same colours, but that the red was more intense than in Sirius; that Procyon contained more blue and purple, and Arcturus more red and orange than Sirius; that Aldebaran contained much orange; and Vega much yellow, green, blue and purple. Of course, Herschel was unable to discern the dark lines in these spectra, but his observation deserves to be remembered as the first application of the prism to starlight.

It is difficult to know whether to admire most the observational skill or the intellectual grasp displayed in these subsidiary researches; and we cannot but feel, with Arago, "a deep reverence for that powerful genius that has scarcely ever erred".

CHAPTER VII.

CLOSING YEARS.

By the beginning of the nineteenth century, Herschel's extraordinary activity began somewhat to abate. Not that his mind had become less acute, or his interest in astronomy less marked. But it was physically impossible for any man to maintain the standard of activity which had been his for thirty years. He had now completed his comprehensive surveys of the heavens, and accordingly his studies became more and more specialised. The Sun and Saturn, the newly-discovered asteroids, and several comets, and last but not least, his experiments on light, occupied more and more of his time. But he now allowed himself intervals of rest between his investigations; he found more time for music, always one of his chief delights, and in addition he gave himself more opportunities for holidays. In July, 1801, accompanied by his wife and his son John, then a lad of nine, he visited Paris. Here he made the acquaintance of Laplace, with whom he had many important conversations, and was introduced to Napoleon, then First Consul. At 7 o'clock on 8th August the Minister of the Interior conducted Herschel, along with Laplace and Count Rumford, to Napoleon's palace at Malmaison. Herschel records in his journal that the First Consul, who met the party in the garden, politely put some questions on astronomical subjects. It was reported at the time that Napoleon's astronomical knowledge had astonished Herschel. Such was apparently not the case. Twelve

years later, in conversation with the poet Campbell, Herschel contradicted this report. "No," he said, "the First Consul did surprise me by his quickness and versatility on all subjects, but in science he seemed to know little more than any well-educated gentleman, and of astronomy much less, for instance, than our own King. His general air was something like affecting to know more than he did know. I remarked his hypocrisy in concluding the conversation on astronomy by observing how all these glorious views gave proofs of an Almighty wisdom." With his keen, quick intuition, Herschel perceived the incongruity of the man of overweening pride and vainglory taking the Divine name upon his lips and simulating a mock piety. The chief result of Herschel's visit to Paris was his election in 1802 as one of the eight foreign associates of the French Institute.

Summer holidays were usually spent at Dawlish, with his lifelong friend, Sir William Watson, and at Tunbridge Wells, Brighton, and Ramsgate. Nevertheless, his health began to fail by gradual stages. His duties as King's Astronomer, nominal so far as scientific work was concerned, were somewhat exacting, and as he grew older he was less able to spend several hours in an evening explaining the heavenly bodies to groups of royal and aristocratic visitors. In October, 1806, the appearance of a bright comet attracted a large number of visitors to Slough. On the evening of the 4th, Caroline Herschel narrates, "two parties from the Castle came to see the comet, and during the whole month my brother had not an evening to himself. As he was then in the midst of polishing the 40-foot mirror, rest became absolutely necessary after a day spent in that most laborious work; and it has ever been my opinion that on the 14th of October his nerves received a shock from which he never got the better afterwards; for on that day (in particular) he had hardly dismissed his troop of men, when visitors assembled, and from the time it was dark till

past midnight, he was on the grass-plot surrounded by between fifty and sixty persons without having time for putting on proper clothing or for the least nourishment passing his lips. Among the company, I remember, were the Duke of Sussex, Prince Galitzin, Lord Darnley, a number of officers, Admiral Boston, and some ladies." This tremendous strain told on Herschel, and the result was that in the spring he became dangerously ill. Caroline tells us that on 26th February, 1807, he was so ill that even she was not allowed to see him, and until 8th March his recovery was despaired of. However, he rallied and recovered, but his health was permanently impaired. But his mind was as clear as ever, and some of his most remarkable papers were written after his illness—that of 1811, in which he developed the nebular hypothesis, and those of 1814, 1817, and 1818, on the construction of the heavens. Physically, however, he was unequal to the task of attending to his great telescopes. On 30th September, 1815, his sister recorded that "his strength is now, and has for the last two or three years, not been equal to the labour required for polishing 40-foot mirrors. And it was only by little excursions and absences from his workrooms he for some time recovered from the effects of over-exertion". During these last years, Caroline's diaries make sad reading, for they record little more than the gradual decay of health and vigour in the "best and dearest of brothers". His inability to repolish his great mirror was a bitter disappointment to him, and he became depressed and sorrowful. She afterwards recorded that "when all hopes for the return of vigour and strength necessary for resuming the unfinished task was gone, all cheerfulness and spirits had also forsaken him. . . . Every nerve of the dear man had been unstrung by over-exertion," so that "a further attempt at leaving the work complete became impossible". In 1819, before his departure for a holiday at Bath, "the last moments before he stepped

into the carriage were spent in walking through his library and workrooms, pointing with anxious looks to every shelf and drawer, desiring me to examine all and to make memorandums of them as well as I could. He was hardly able to support himself, and his spirits were so low that I found difficulty in commanding my voice so far as to give him the assurance he should find on his return that my time had not been misspent."

But Herschel was not always, even in extreme old age, depressed and gloomy. A German visitor to Slough, in 1819, thus described the great astronomer: "While we were standing by the great telescope, which we more admired than comprehended, its master appeared, a cheerful old man aged eighty-one. How unassumingly did he make his communications! How lightly did he ascend the steps to the gallery! With what calm pleasure did he seem to enjoy the success of his efforts in life. All accounts from his native country seemed to please him, although the German language had become somewhat less familiar to his ear. After a short conversation, we took our leave, charged with friendly greetings to all beyond the sea who might still remember him."

On 5th April, 1816, he received the first mark of recognition from the British Government—the third class of the Hanoverian Guelphic Order. In the following month he was created a Knight of the same Order. In 1820, when the Astronomical Society of London—now the Royal Astronomical Society—was founded, Herschel was elected as the first President. His health did not permit him to attend the meetings, but he communicated his last paper—on double stars—to its "Memoirs" in 1821.

Caroline Herschel's Memoirs record the agony of soul through which she passed as her brother became weaker and weaker. In 1819 he sent a note across to her lodgings, notifying her of the appearance of a "great comet".

She preserved this, with the comment, "I keep this as a relic! Every line *now* traced by the hand of my dear brother becomes a treasure to me." Her own health was seriously impaired, and she sometimes expected to pass away before him. But a different fate was in store for her. The hot summer of 1822 told heavily upon Herschel, but apparently no imminent danger was anticipated, for his son John, then a graduate of Cambridge, started on the 8th of August for a tour on the continent. On the 15th, "after half-an-hour's vain attempt to support himself," the faithful chronicler relates, "my brother was obliged to consent to be put to bed, leaving no hope ever to see him rise again". Ten days later, 25th August, 1822, he passed away, within three months of completing his eighty-fourth year. He was buried in the church of St. Lawrence at Upton, near Slough. The long Latin inscription claims for him that "coelorum perrupit claustra"—"He broke through the barriers of the skies".

The end was not unexpected, but to his devoted sister—the companion and co-worker of a lifetime—the loss was irreparable. After his death, she tells us, there was but one comfort left her, "that of retiring to the chamber of death, there to ruminate without interruption on my isolated situation. Of this last solace I was robbed on the 7th September, when the dear remains were consigned to the grave." Her own life, she felt, was finished; she had no further interests. And so she decided to leave England and return to Hanover and the scenes of her girlhood, there to spend the evening of her days. There was another reason for her decision. Only one of her brothers now survived; Alexander had died a year before William, and sentimental reasons impelled her to make her home with Dieterich. In the midst of her deep sorrow she had made over to Dieterich—shiftless and impecunious as ever—her little capital sum of £500; in her own words, "I gave myself, with all I was worth, up to my brother Dieterich and his family". No sooner

had she arrived in Hanover, in October, 1822, than she realised her great mistake. She found herself among uncongenial company. "In the last hope of finding in Dieterich a brother to whom I might communicate all my thoughts of past, present and future," she wrote to her nephew in 1827, "I saw myself disappointed the very first day of our travelling on land. For let me touch on what topic I would, he maintained the contrary, which I soon saw was done merely because he would allow no one else to know anything but himself." The old lady could find no congeniality in the company of a soured, fractious old man, and among people who could not enter in the slightest into her scientific interests. "From the moment I set foot on German ground," she said, "I found I was alone." She described herself as leading a "solitary and useless" life—"not finding Hanover or anyone in it like what I left when the best of brothers took me with him to England in August, 1772".

Solitary her life was, so far as congeniality went, but by no means useless. Soon after her settlement in Hanover, she formed a catalogue of all her brother's nebulæ and clusters, arranged in zones. In April, 1825, she forwarded this to her nephew, John Herschel, then engaged in his review of these objects. This catalogue was described by Sir David Brewster, as "an extraordinary monument of the unextinguished ardour of a lady of seventy-five in the cause of abstract science". It was rewarded by the presentation to her of the Gold Medal of the Royal Astronomical Society, in 1828—an honour by which, with characteristic modesty, she said she was "more shocked than gratified". In 1835 she was elected an honorary member of the Royal Astronomical Society, membership of which was not then open to women; and in 1838 the Royal Irish Academy enrolled her name among its members. These honours sat very lightly on her. "Saying too much of what I

have done," she said in 1826, "is saying too little of him, for he did all. I was a mere tool which he had the trouble of sharpening and adapting for the purpose he wanted it, for lack of a better."

As the years passed, and her vitality ebbed, all her affection became concentrated in the one being whom she felt understood her and with whom she had community of interests—her nephew John. She followed his career with pride, as a worthy sequel to that of his father; his visits to Hanover were to her oases in the desert of her experience; he and his wife were her principal correspondents. She wrote her last letter to her nephew, December 3rd, 1846: she was then ninety-six, and had survived her brother for twenty-four years. During 1847, tenderly nursed by her niece, Mrs. Knipping, the only one of Dieterich's family who really sought to care for her, she slowly sank, and on 9th January, 1848, she passed away—within two months of completing her ninety-eighth year. She was buried beside her parents in the churchyard of the Gartengemeinde at Hanover. Her epitaph, composed by herself, records that "the eyes of her who is glorified were here below turned to the starry heavens. Her own discoveries of comets and her participation in the immortal labours of her brother, William Herschel, bear witness of this to future ages."

Future ages are not likely to forget Caroline Herschel. Her own original work was, it is true, comparatively small; but her self-sacrificing devotion to her brother, her performance of the countless small petty drudgeries of his scientific life, her tender care for his welfare and comfort, give her an honourable place among women of lasting fame. As long as William Herschel is remembered, his sister Caroline will not be forgotten. As has been truly said, "she shines and will continue to shine by the reflected light that she loved".

The career of the younger Herschel was, in many

respects, the sequel to, and completion of, that of his father. John Frederick William Herschel, born "within the shadow of the great telescope," on 7th March, 1792, was educated at Hitcham, Eton and Cambridge. At the University he was a distinguished student, particularly in mathematics, and graduated as Senior Wrangler in 1813. He was in no hurry to choose his life-work, nor was there any need. Since his father's marriage, the family had been in easy, if not affluent circumstances. His father had destined him for the Church, but he preferred the study of law. He never practised at the Bar, however, and at last decided for a scientific career. In 1816 he informed a correspondent that he was "going under his father's directions to take up star-gazing". He had at first no definite inclination in that direction, but he decided to complete his father's work. During his father's lifetime, he re-examined many binary stars, in conjunction with Sir James South, and for these observations he received the Lalande Prize of the French Academy and the Gold Medal of the Astronomical Society.

In 1828 he succeeded in rediscovering the genuine satellites of Uranus, and in the same year commenced his review of his father's nebulæ and star-clusters. The completion of this work was signalised by knighthood. Then, in 1833, after his mother's death, he decided to extend his father's surveys to the southern hemisphere. He transported his great telescope to Cape Colony, and at Feldhausen, near Cape Town, from 1834 to 1838, he swept the southern skies, cataloguing double stars, clusters and nebulæ; and after nine years of arduous labour, the monumental volume known as "Results of Astronomical Observations at the Cape of Good Hope" was published. Meanwhile, honours were showered thick and fast upon the astronomer; he was created a baronet after his return from South Africa, many degrees were conferred upon him, and learned societies

vied with each other in enrolling his name among their members. On his return to England, he did not re-erect his telescopes; and his career as an observer was closed. During the latter part of his life he was regarded as the greatest English astronomer of his day, and on his death on 5th May, 1871, at his home at Collingwood in Kent, he was interred in Westminister Abbey, close to the grave of Newton.

Sir John Herschel was survived by three sons, of whom only the eldest, Sir William James Herschel (1832-1917), did not inherit the family taste for astronomy. The second son, Alexander Stewart Herschel (1836-1907), Professor at Durham College, devoted considerable attention to meteoric astronomy, while the younger son, Colonel John Herschel, in his earlier days undertook a spectroscopic examination of southern nebulæ. The names of a grand-daughter and of a great grandson of Sir William Herschel—Miss Francesca Herschel and Rev. J. C. W. Herschel—appear on the roll of Fellows of the Royal Astronomical Society, to testify that the family is still distinguished by love of the oldest of the sciences.

CHAPTER VIII.

PERSONALITY AND INFLUENCE.

SCIENTIFIC biographies are sometimes painful reading—painful because in them we are occasionally brought face to face with the flaws in great characters, the pettinesses of great minds. The biography of Herschel does not belong to that class. The character which shines through his writings, through his sister's memoirs, and through the correspondence and comments of contemporaries is that of a genial, kindly, earnest man. In private life he was a good husband and father, a loving brother and a devoted son. His less fortunate relatives found in him a ready and willing helper: he maintained his brother Alexander after his retirement until his death in 1821. Even to Dieterich, the shiftless member of the family, he was unfailingly kind and sympathetic, bequeathing to him a sum of £2000. From earliest years he was to Caroline "the best and dearest of brothers," and that his care for her did not close with his death is evident from his bequest to her of an annuity. Alike in times of adversity and prosperity, he was ever helpful and kind.

He had none of that aloofness which has often characterised men of science. He was at all times ready to reply to correspondents and to answer inquiries. He was always accessible and never pedantic. The poet Campbell has given us a charming word-picture of the astronomer in private life. Writing to a friend on 15th September, 1813, Campbell said: "I wish you had been with me the day before yesterday, when you would have

joined me, I am sure, deeply in admiring a great, simple, good old man—Dr. Herschel. . . . His simplicity, his kindness, his anecdotes, his readiness to explain—and make perfectly conspicuous too—his own sublime conceptions of the Universe, are indescribably charming. He is seventy-six, but fresh and stout, and there he sat nearest the door at his friend's house, alternately smiling at a joke, or contentedly sitting without share or notice in the conversation. Any train of conversation he follows implicitly; anything you ask he labours with a sort of boyish earnestness to explain. . . . Speaking of himself he said, with a modesty of manner which quite overcame me, when taken together with the greatness of the assertion, 'I have looked further into space than ever human being did before me. I have observed stars of which the light, it can be proved, must take two millions of years to reach this earth'."

Herschel's close friendships were few but enduring. Sir William Watson, Sir Joseph Banks, Dr. Maskelyne, and Mr. Aubert, were intimate friends and correspondents of many years' standing. Among continental astronomers, Lalande, Bode, and Schröter, were the most frequent correspondents. With men of science his relations were as harmonious as with humble amateurs or anxious inquirers. No acrimonious controversies disturbed the even tenor of his scientific career. The nearest approach to heat was in his paper of 1793, when he made his spirited refutation of Schröter's alleged discovery of high mountains in Venus; and on that occasion his words were probably written more in the spirit of banter than controversy. At least, Schröter seems to have so regarded them, for the two astronomers continued to be friendly correspondents.

His mind was many-sided, and to the end his interests were varied. His love for music never left him, nor did that early interest in metaphysical and logical reasoning which prompted the seventeen-year-old musician to spend all

his earnings on a copy of Locke's "Essay on the Human Understanding". His early contributions to the Bath Literary Society included a number of philosophical papers. One of these dealt with the "utility of speculative inquiries". In this there occurs the following passage, which gives us some idea of the catholicity of his mind and also an insight into the secret of his success as a man of science: "It was said that speculation and metaphysics were of little use to mankind. This I deny. The perfection of our nature is evidently to be looked for in the superior powers of reason and speculation. What would all experiments avail if we should stop there and not argue upon them so as to draw general conclusions? And how can we argue and draw conclusions if the superior intellectual powers are not improved by frequent exercise in speculative researches? Half a dozen experiments made with judgment by a person who reasons well are worth a thousand random observations of insignificant matters of fact. But setting aside the very obvious consequences of improved faculties, the subjects of mere speculative knowledge are of the highest concern to those who love wisdom. By metaphysics we are enabled to prove the existence of a First Cause, the Infinite Author of all dependent beings. By mathematics we come to have a just idea of the superlative perfection of His works. By logic we can prove them to others. By ethics we are made sensible of our duty towards the Author of our existence and to our fellow-creatures."

This full-orbed conception of the world seems to have saved Herschel from falling under the influence of the spirit of scepticism then prevalent among men of science. In his mind—keen and logical as it was—there seems to have been no conflict between the scientific and religious instincts. In a letter to a correspondent, dated 1st January, 1794, he said, quite simply and without affectation: "It is certainly a very laudable thing to receive instruction from the great Workmaster of Nature,

and for that reason all experimental philosophy is instituted".

In his paper on the "Construction of the Heavens," in 1785, he wrote, "We ought to avoid two opposite extremes. If we indulge a fanciful imagination and build worlds of our own, we must not wonder at our going wide from the path of truth and nature. . . . On the other hand, if we add observation to observation without attempting to draw not only certain conclusions but also conjectural views from them, we offend against the very end for which only observations ought to be made." This principle he maintained throughout his life. We can trace its operation through all the wonderful series of papers which he communicated to the Royal Society. In regard to the Milky Way, to island universes, to the nature of nebulæ, to double stars, to the Sun and planets, we see him collecting facts, framing hypotheses to account for these facts, and testing them by further facts. He had no fear of propounding theories, nor had he hesitation in withdrawing them. Theories were to him means to an end—the discovery of truth.

The career of Herschel marked an epoch in astronomy. His powerful genius directed the course of the science in the nineteenth century; and modern astronomy still bears the impress of his massive mind. When he began his long career as an observer, astronomy had become more or less a branch of applied mathematics. Such was not to be wondered at; the immediate task of the eighteenth century was the proof of the universal validity of the Newtonian law—a task carried forward to a triumphant conclusion by Lagrange and Laplace. But one result of the concentration of energy on the mathematical side of the science was that the study of the physical condition of the Sun, Moon, and planets was largely neglected; while the stellar branch of astronomy was virtually non-existent.

As a result of his development of the powers of the

telescope, Herschel was enabled to take the whole field of observational astronomy for his province. He enormously extended knowledge of the Sun; and his solar theory, untenable though it proved, was the first attempt to systematise and co-ordinate the known facts concerning the Sun. His work on the various worlds of the Solar System marked the foundation of modern planetary topography. His paper on Mars in 1784 constituted Martian astronomy a distinct branch of the science. The scientific study of the Saturnian system may be said to have begun with him; he was the author of the first serious attempt to explain the atmospheric phenomena on Jupiter. He not only discovered Uranus—and thus prepared the way for the discovery of Neptune—but he persistently scrutinised its disc until he ascertained its size and mass. His discoveries of satellites did not exhaust his work on the secondary systems. His remarkable intuition that the rotation periods of satellites are equal to their times of revolution was one of the flashes of his genius.

In stellar astronomy he discovered binary stars, and thus proved what others had suspected—that the law of gravitation was of universal application. With consummate skill and audacity he attacked the highly difficult and elusive problem of the solar motion, and successfully measuring its rate and direction, he demonstrated further the essential kinship of Sun and stars. His efforts to know the construction of the heavens were unsuccessful, but he laid the foundation of a new branch of astronomy—that dealing with the distribution and motions of the stars; and in addition discovered suns and worlds in process of formation. Herschel was the first student of nature to point to evolution in progress and to classify natural objects in evolutionary array.

Above all, Herschel enormously widened the mental horizon of man. His researches extended the universe

both in space and time—in very truth, "he broke through the barriers of the skies". He revealed to the wondering gaze of his contemporaries star upon star, system upon system, cluster upon cluster. Speaking of these revelations Horace Walpole said: "If there are twenty millions of worlds, why not as many and as many and as many more? Oh, one's imagination cracks!" His researches revealed the Earth in its true light—one revolving globule chained to a tiny star; a dust-grain in the infinite.

Every branch of observational astronomy bears to this day the impress of Herschel's powerful personality. Since his death, the science has greatly advanced; its horizons have widened, and innumerable new facts have been brought to light. Yet, even to-day, we cannot but agree with the verdict of a prominent American astronomer[1] that Herschel "was so far in advance of his age that we are just now beginning to appreciate his genius," and we may safely say that in the annals of astronomical science the name of William Herschel, pioneer of modern astronomy, will shine with increasing lustre as the years roll on. To him, indeed, we may apply, with peculiar fitness, the beautiful words of Longfellow:—

Were a star quenched on high,
For ages would its light,
Still travelling downwards from the sky,
Shine on our mortal sight.

So when a great man dies;
For years beyond our ken
The light he leaves behind him lies
Upon the paths of men.

[1] Prof. T. J. J. See.

APPENDIX.

I. CHIEF DATES IN HERSCHEL'S LIFE.

Born at Hanover, 15th November, 1738.
Settled in England, 1757.
Appointed organist of Octagon Chapel in Bath, 1766.
First recorded astronomical observation, 19th February, 1766.
Began to construct telescopes, 1773.
First recorded telescopic observation, 1st March, 1774.
Discovery of Uranus, 13th March, 1781.
Elected Fellow of the Royal Society, December, 1781.
Appointed as King's Astronomer, 1782.
Discovery of Proper Motion of Solar System, 1783.
First paper on the Construction of the Heavens, 1784.
Disc-theory of the Universe propounded, 1785.
Marriage, 8th May, 1788.
Investigation of nebulous stars, 1791.
Discovery of revolving double stars, 1802.
Abandonment of disc-theory and enunciation of nebular hypothesis, 1811.
Last paper published, 1821.
Died at Slough, 25th August 1822.

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